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PREFACE.

THE desire of obtaining knowledge is one of the most natural, and, at the same time, most ennobling attributes of the human mind, for it is impossible, whatever may be our station in life, to walk through the world without noticing facts of the highest interest, which cannot be duly appreciated unless properly understood.

The Panorama of Science is intended, like a guide-book to strangers, to lead our readers through the most agreeable paths to knowledge, and explain in the most simple manner the Principles of Science. No scholastic difficulties will be allowed to impede our progress; for there is now no necessity to effect, like the priests of old, an air of mystery in elucidating the artless means which nature takes to accomplish many of her most important and beautiful operations: indeed, truth disdains all artifices; she does not love to appear masqueraded in the custom of quaint and hyperbolical devices; her ways are ways of the utmost simplicity, and may be readily understood by every individual desirous of acquiring information. This information we will now lay before the reader, excluding, or explaining, all scientific terms; and it is hoped that this will appear a "Panorama" more than in name.

G. G.

Liverpool, May, 1852.

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THE
PANORAMA OF SCIENCE.

INTRODUCTION.

SCIENTIFIC knowledge has often been neglected from an idea that it can only be attained by individuals who previously possess considerable information. There cannot possibly exist a greater mistake; for Nature is so simple in all her operations, that they can be rendered as intelligible to the mind of the humble mechanic or unlettered peasant, as to that of the haughty peer or the most learned philosopher. It is certainly true, that in former times, partly from ignorance, or the defects of the English language, and from an ignoble wish to fetter the progress of the human mind, the most simple truths were studiously obscured; but the curious signs and figures—the harsh and disjointed phraseology—the crude and complicated technical terms which were then in general use, have now been done away with, and the path to the Temple of Science is at the present day open and easy of access to all.

In this age of intellectual excitement many means have been contrived to extend the blessings of education; and schools of art have been instituted, and popular lectures judiciously delivered, with the view of communicating, in the most easy and familiar manner, those principles of science which explain the various phenomena of nature, and the different processes of art by which we can supply the necessaries and the luxuries of life. But it is now our intention in publishing this volume, to *bring home to every fireside in the kingdom*, that species of information, which has hitherto been confined to schools and lecture-rooms, or published in an expensive or too elaborate form for general use. To obviate every difficulty, therefore, and to render the scientific subjects of which we are about to treat, adapted to the capacity of even the most illiterate of readers, the most perfectly simple style of language will be used in the composition of the following articles.

Science admits of two general divisions; the first comprehending an investigation into the nature and operations of our own minds; the second, into the various properties and conditions of matter, or the objects which we perceive in the external world. It is by a strict examination into these, that we become acquainted with the laws of Nature, without some acquaintance with which we must be continually passing over many objects and events unnoticed, that would otherwise excite the greatest possible interest and admiration. Nor is this all; for when any event does occur of so uncommon and striking a kind as to attract our attention, and so to awaken our ignorance, if we are unable to explain it on fixed principles, we must fall back upon the suggestions of fancy which, as every person has found, lead to the most absurd and extravagant superstitions. Thunder and lightning, comets, meteors, northern lights, rainbows, and indeed every phenomenon of Nature, has, in its turn, excited those superstitious feelings which appear natural to man while in a state of ignorance; but happy are we that such is not the condition of the working men of the nineteenth century—the schoolmaster is abroad, and a *cheap* press has wrought miracles. But a few examples will not be out of place here to show the advantages we enjoy over what our forefathers enjoyed.

In ancient times, thunder and lightning were regarded as occurrences beyond the common course of nature. Under the Mosaical dispensation, the Jews were accustomed to open the doors and windows of their dwellings during a thunder storm, in the expectation of the promised Messiah making his appearance amidst this war of the elements. The Roman Catholics, in many districts of Germany, toll the bells of the churches during the continuance of a thunder-storm; and in Athens, when a person was struck dead by lightning, the spot on which the accident occurred was enclosed, and an altar raised for the people to offer up their sacrifices to the gods. The superstitions of the ignorant which gave rise to such customs, have, from the rapid advancement in our own days of the knowledge of science, not only been dispelled, but we have contrived by a very simple expedient, to rob the cloud of its lightning, and to protect our houses and churches from its disastrous effects. Comets have also been, from a very early period, regarded as unnatural events, which appeared in the heavens to predict the most dismal calamities, such as wars and pestilence, the dethronement and death of kings, and the destruction of empires. By referring to the history of Rome we will observe the undue importance which was attached to the comet that appeared a short time previous to the Augustan war, and to that which attended the battle of Pharsalia: neither has Josephus, the celebrated Jewish historian, been sparing of them at the destruction of Jerusalem. During those days of ignorance and superstition, comets were merely regarded as flaming meteors: but thanks to the progress of discovery, our astronomers are now enabled to examine their nature more minutely—to point out the orbit they describe—and to foretell with certainty the periods of their return. Meteors, which occur so much more frequently than comets, have also aroused the apprehensions of the vulgar, who have fancied them to bear away the spirits of the departed, and to be the sure forerunners of death. "The account," says Mr. M'Pherson, "given to this day by the ignorant, is very poetical. The ghost comes mounted on a meteor, and surrounds twice or thrice the house destined for the person to die in, and then goes along the road through which the burial is to pass, shrieking at intervals; at last the meteor and the ghost disappear above the burial place." Northern lights have also given rise to many conjectures and prophecies. If of a pale colour, they were supposed to be the precursors of famine; if of a brilliant red appearance, to be ominous of pestilence and war. The rainbow even, which "compasseth the heaven about with a glorious circle," has been the parent of numerous fanciful notions. The superstition of the Athenians caused altars to be raised for its worship; and even to the colours it exhibits were assigned a mysterious interpretation during the earlier ages of Christianity. The red and green colours were considered to be significant of the destruction of the world with fire and water; while in the other colours were recognised typical allusions to the mysteries of baptism and the holy sacrament of the Supper. These, and many other false notions we could point out, shew, that without some knowledge of the elementary principles of science, we not only fail to observe and appreciate, but are apt to place an absurd and mischievous interpretation on the most interesting and beautiful phenomena of nature.

By the aid of scientific principles, derived from the observation of a few facts of the most simple kind, and which are capable of immediate proof, the weakest disciple of science has it in his power to explain the properties and effects of light—the sources, operations, and numerous applications of heat—the composition of air and water, and the various kinds of earths, minerals, metals, and other substances of which this globe we inhabit is composed. Besides all these, there are many phenomena of frequent occurrence which claim peculiar attention; the varied and frequently beautiful colours that are often observed reflected along the sky—the formation and varieties of clouds—the condensation and fall of snow, hail, rain, and dew—the motions of the air, sea and land breezes, trade-winds, whirlwinds, the hurricane, the tornado, and the simoom—the various appearances which prognosticate change of weather—the transparency, the glowing tints and depths of the ocean, with the motion of its waves, its tides, its currents, and its whirlpools—the lakes, rivers, and springs, which so beautifully diversify the face of nature; the terrible convulsions which, under the form of earthquakes, lay the proudest cities in the dust, and overwhelm with fear the heart of man—these and many other wonders of creation, are well calculated to excite, even in the most heartless mind a spirit of inquiry, which, once aroused, will go along upon its path rejoicing, fully conscious that at every step it is gathering power and enlarging the boundaries of human happiness. All mankind, natural historians, moralists, poets — are accustomed to speak of the surpassing beauties of nature; but these cannot be felt nor sufficiently appreciated without being properly understood; therefore this is one of the strongest inducements for us to cultivate such knowledge — to apply ourselves to obtain a clear perception of the globe we inhabit; for whatever may be the sphere of life in which we are destined to move—whatever the duties we may be called upon to perform, or the cares and anxieties that may oppress us, there are times when we escape from these into the free open air, to wander perhaps through the green fields, or along the sea shore, and then the mind so endowed carries along with it a talisman, by which it can at all times command the most interesting subjects for its contemplation. But besides the foregoing inquiries, which relate principally to what is termined inorganic matter, when we have examined the irregularities of the earth's surface, its mountains and its valleys—its hills and its plains—its its stupendous rocks and its level shores, it will remain for us to consider the numerous tribes of organic beings which in these different regions find their appropriate abode. We shall find that the vegetable creation alone opens up to us a world which first bewilders us with the multitude of its wonders and beauties, and then charms us into meditation. Every plant, from the humble moss clinging to the barren rock, to the majestic oak of the umbrageous forest—from the despised weed on which we disdainfully trample, to the beautiful flower which it is our delight to cultivate, are under the influence of the same unalterable laws; they all require light, heat, air, and moisture; they all possess a living principle, and require a certain quantity and kind of nourishment which is distilled into sap, and converted in different kinds of matter, for the leaves, flowers and fruit; they have all the faculty of reproduction, whereby the same species is continued, and they all grow, attain maturity, and then die, and their decayed remains, even as human dust, then contribute to the formation of the soil, which is always by such means in the course of renewal. The seeds and fruits of some of these plants, by various processes of art, are converted into food, examples of which we have in the numerous kinds of grain now cultivated in Europe; others again which snpply us with the means of clothing, instances of which we recognise in the hemp, flax, and cotton plants; others produce valuable medicinal substances, by which we are enabled to lessen and often entirely subdue the sufferings and progress of disease; besides all which, it is almost unnecessary to add that timber of different kinds forms a most important article of commerce, seeing it is applied to so many purposes of life.

From all this we perceive that the vegetable kingdom not only adorns the world with verdant beauty, but that all its productions, its grasses, herbs, shrubs, and trees, are adapted to supply the various wants of the great human family. But it is not man alone that derives support and enjoyment from that source; the plants that grow beside rivers, the shrubs that beautify rocks, the extensive forests formed by the grouping together of trees,—all afford nourishment and protection to thousands of living beings. Here myriads of insects that have hitherto escaped the observation of the naturalist, and birds whose melodious warblings are unrivalled by human art, enjoy their liberty; here, also, secure from the dominion of man, animals, in their wild and undomesticated state, find shelter. As the principle of life which exists in plants does not lead to the obvious manifestation of any sentient or thinking principle, they have been placed at the bottom of the scale of organised beings, ascending from which the numerous living beings that inhabit the air, the water, and the earth, and which exhibit a regular advancing scale, from the most simple to the most complicated structures, engage our attention and our interest. Certain general laws we find govern all these—they all require light, heat, air, and food—they all have the power of multiplying their individual and distinct races—they all grow and enjoy the power of locomotion—they have all senses which warn them of the approach of danger, and enable them to select the most proper substances for their support—they have all their appropriate residences, some being the inhabitants of cold, others of hot climates, some being destined to live in the bosoms of valleys, others on the heights of mountains—they have the habits which are connected with certain peculiarities visible in the form of their bodies—they all endure only a temporary existence, some of them living only a few minutes, others for centuries: and finally, like the plants already noticed, the remains of their decaying bodies contribute to the formation of the earth on which we tread. Finding himself perplexed, by the immense number of these animated beings, the naturalist has arranged them according to their various forms and habits into certain general divisions, and these again he has subdivided into particular classes, genera, species, and varieties. At the head of these, pre-eminently distinguished by the faculty of speech, and the powers of his mind, we find man, whose knowledge, when tempered with humanity, teaches him humility, forbearance, and gentleness to all living things. In his uncivilised state man is perhaps the most abject and helpless creature that moves on the face of the earth; nor is it until the light of reason draws upon his soul that he can understand how to supply his numerous necessities and comforts. Naked, unarmed, exposed to all the inclemencies of the weather, he seeks only to supply his immediate physical wants. His hunger he appeases by eating the fruits of the trees, or the roots of herbs; his thirst he quenches at the river's brink, and his abode is in the depths of otherwise unfrequented forests. In this state he has no language to explain his ideas; but let us turn from a picture so humiliating to human vanity, and contemplate man in his more civilised condition, enjoying not only all the comforts, but likewise the luxuries conferred on him by the progress of the arts and sciences. Imperial Rome, formerly the mistress of the world, originally consisted only of a few mud hovels irregularly scattered, and we are informed by Vitruvius, that even in his time, the Temple of Romulus was thatched with straw for its preservation. Such was the origin of that proud city; and this is only an emblem of the significant changes, improvements, and contributions to happiness that have been, and will be effected, by the progress of the human mind.

Great Britain itself, which has held so commanding an attitude among surrounding nations, has also risen from as humble an origin; and to what can her glory and prosperity be attributed? Undoubtedly to the advanced state of the arts and sciences; it is this which led to her conquests both by land and sea; and it is this which now forms the broad and firm basis of her commerce. The application of the principles of science to her various manufactures has brought many of them to a state of the most wonderful perfection. When we consider, therefore, that the knowledge of the principles of chemistry will enable us to understand the most interesting processes of art, no one will deny that it is a most desirable acquisition, more especially as it requires but little sacrifice of time and no great application to study. By referring to the History of Great Britain we will learn that previous to the eighth century glass was an article unknown, and that the windows of houses, and even of cathedral churches, admitted light through fine linen cloths, or lattices of wood; but now, by the union of potash and a certain kind of sea sand, and the application of heat, glass is formed, which supplies us with the means of enjoying light in our habitations, while at the same time it excludes the inclemency of the weather; and the manufacture of glass at the present day forms an important branch of our trade. The art of bleaching, dyeing, and tanning, are likewise chemical operations, which may be understood with little difficulty. The process of bleaching is one of great antiquity; for we are credibly informed that lime was used in bleaching, three hundred years before Christ. Here the bleacher has been indebted to the progress of science, as without knowing the elementary principles of which, it is not possible to understand the action that takes place in this process. In dyeing, not a colour can be imparted unless an affinity or attraction exists between the cloth and the dye; and if this is not present, recourse must be had to some other agent to form a bond of union between them. For example, if we dissolve some indigo in a little common vitriol, and dilute it largely with water, and then dip into the solution a piece of silk, linen, or cotton, we shall find, on taking it out immediately, that the indigo combines with the cloth and gives it a blue colour; but if, in the place of indigo, we use cochineal, or madder, and immerse the cloth, we shall find that there is so slight an attraction between the colouring matter and the fibres of the cloth, that it only receives a stain which may be removed by washing. In this case a mordaunt or basis, generally a preparation of iron or tin, is requisite to render the dye permanent. We hereby perceive that the process of dyeing depends on a chemical action, which admits of a very easy explanation. Tanning, likewise, can only be understood, by having recourse to the science of chemistry, which has taught us that, in the rind or bark of trees, more especially of the oak kind, a substance is found which may be made, by a very simple process, to combine with the skins of animals, so as to form leather. The mode of extracting metals, also, from their different ores, and the important art of agriculture, require a knowledge of chemical principles. Besides these, even the most simple culinary processes, daily going forward in our kitchens, proceed likewise on principles of chemistry, which every individual ought to understand. We are informed that Count Rumford, the distinguished philosopher, did not disdain to exercise the powers of his scientific mind in devising means to improve the art of cooking. He endeavoured to ascertain how the greatest quantity of nourishment could be obtained from food at the least possible expense; and so successful was he in his experiments, that, in one of his establishments at Munich, three women prepared a dinner for a thousand persons, and burned only nine-pence worth of fuel. He proceeded so far in his improvements so as to economise all the heat of the smoke; and it was even believed, had he lived, he would have cooked his own dinner with the smoke from his neighbour's chimney. Many more examples might be here brought forward to illustrate the universal application of the principles of science, but sufficient has been said to point out how much there is to delight as well as to interest the student as he advances along the path of useful knowledge. We may observe that the instruction which thus enables us to appreciate the beauties of nature, and qualifies us to understand the various processes of art, should exercise the happiest and most beneficial effects on human character; for such meditations are every way calculated to elevate the thoughts, refine the feelings, enrich the imagination, aud render us happier as we proceed on our journey through this world, and at the same time making us better fitted for the enjoyment of a glorious eternity.

LIGHT.

"In the beginning God created the heaven and the earth. And the earth was without form, and void, and darkness was upon the face of the deep: and the Spirit of God moved upon the face of the waters. And God said, Let there be light: and there was light."

The accomplishment of the divine command was immediate, and the sudden removal of the dismal darkness which was upon the face of the deep was instantaneously followed by the bright splendour of the sun. The transition presented over the whole appearance of the now illumined, face of the waters, must fill every thoughtful mind with a sense of power and sublimity which cannot be exceeded. We cannot feel surprised that this light, so unsullied in its nature, and so lovely in all its different effects, suddenly called into existence, —we cannot feel surprised, we repeat, that this light, which so freely scatters its blessings around us, should have attracted the attention of the most highly gifted and accomplished philosophers. Let us then enter on this interesting subject, and proceed to consider its nature and properties, and its influence on the animate and inanimate creation.

The sun, which has been worshipped as a visible god by many nations, is the most obvious source of light and heat; and every one is now, or ought to be aware, that it is the change of position which our earth, in its constant revolution, undergoes in its relation to that luminary, which causes and regulates the return and duration of day and night, and the succession and intensity of the different seasons. But the sun is not the only source of light; for was this the case we should be left during the period of night in the helplessnes of darkness, than which nothing could be more dreadful. Instead of this, however, when the sun has sunk below the horizon, and the twilight which follows has faded away, the reflected light of the moon, and the light of innumerable stars, shed a soft and sparkling lustre through the world. These heavenly bodies are the most obvious sources of natural light; but man, at a very early period, prompted by his necessities, contrived to procure both light and heat artificially, to accomplish which, he had recourse to several ingenious plans. It was observed, that when two bodies are pretty smartly rubbed against each other, both light and heat are obtained by the friction. The arctic Highlanders of Baffin's Bay obtain fire by rubbing two fish bones against each other. The Fuegians, an uncivilised race of people, inhabiting one of the coasts in the Southern Ocean, procure fire by rubbing a pyrite, or firestone, and a flinty stone together, and catching the sparks on a soft dry substance, resembling moss, which is quickly ignited. The inhabitants of New Holland take two pieces of soft dry wood—the one a stick about eight inches long, and the other a flat piece; the stick is shaped into a blunt point at one end, and pressed firmly against the piece of wood, holding it between both their hands, and turning it quickly round. By this method light and heat are obtained, in somewhat less than two minutes. It is for this reason necessary to grease the iron at the axis of carriage wheels, as otherwise from the friction, when the carriage is drawn swiftly along, as on railways, they are apt to take fire—an accident which has frequently cccurred. Friction, therefore, is one of the sources of artificial light. When one body is quickly struck against another—say a piece of flint against a piece of iron—light and heat are likewise produced. This is the method of obtaining light and heat by percussion; and it is well known that advantage is taken of it in the locks of guns and pistols. When fire has been thus produced, it is applied to an inflammable body, during the burning of which, a more or less bright light is emitted. Thus oil and tallow are inflammable substances, and by putting in either of these, a piece of cotton wick, and lighting it, the oil or tallow rises through its threads and produces a steady flame. Many gases are likewise inflammable, and when mixed together in certain quantities, consume more or less rapidly.

Light is also produced by electricity, which is a very peculiar and subtle fluid, that seems to pervade in a greater or less degree all bodies, animate or inanimate. When this electric fluid has accumulated in any particular region, it seeks to disperse or equalise itself, and in so doing, evolves itself, and becomes perceptible to our sight. This is the cause of lightning; and many are of opinion that it is likewise the cause of the aurora borealis, meteors, shooting stars, and other interesting phenomena in nature. Certain animals also have the power of generating a phosphorescent kind of matter, which gives out light, such as the glow-worm, the fire-fly of the West Indies, and some descriptions of fish. It is probable that sea-water is capable of dissolving this luminous matter, which explains the reason why the waters of the ocean by night often appear shining when agitated. Such are the general sources of light. But the principal, and most constant of them all is undoubtedly the sun.

Naturally inquisitive, the human mind is next led to inquire what is the nature of this light which is so universally spread over the world, and what are its properties; nor have these subjects remained uninvestigated. The celebrated philosopher Descartes was of opinion that light is caused by a certain motion or undulation of a very thin elastic medium, which he supposed pervaded space; but Sir Isaac Newton, whose valuable discoveries established a new era in the history of science, discarded this doctrine, and from various observations, came to the conclusion that light consists of very minute particles of matter, which are thrown out in all directions from luminous bodies. The opinion of Descartes was afterwards supported by many scientific men of eminence; but the views of Sir Isaac Newton appear better founded, and are consequently more generally countenanced. The particles of light are extremely small, nay, so exquisitely minute, that they do not affect the most delicate balance; but when we call to our recollection, that objects exist of such extreme minuteness as to escape even the powers of the microscope, so also does matter exist of so subtile a nature as not to affect the most exact scale that has as yet been constructed. This is the case with the matter of heat, and also with that of electricity. "We may weigh, perhaps, the thousandth part, of a grain, but," says Dr. Thomson, "we are certain that no particle of light weighs the *one millionth millionth* part of a grain." This exquisite minuteness of the particles of light enables them to enter freely into the eye, without inflicting the slightest injury on the structure of so delicate an organ. Rare, indeed, is the adaptation of every arrangement of nature to fulfil its final end or purpose. The number of these particles which flow from every luminous body is also wonderful. It has been estimated that there flow more than six million million times as many particles of light from a candle in one second of time as there are grains of sand in the whole earth. Be this as it may, the particles of light from a single candle, if there be no obstacle in the way to obstruct their passage, will fill a space of two miles in distance in every direction. The velocity with which light travels has equally excited the wonder and admiration of every intelligent mind. The sun is above ninety millions of miles distant from our earth, yet its light reaches us in about seven minutes and a half.—Dr. Brewster says, that it moves at the rate of a hundred and ninety-two thousand five hundred miles in a second. But while we pause on this surprising velocity, it may be well to recollect that all our notions of distance and time are merely comparative, and in this, as in many other instances, our ideas are confined to the limits of our own circumscribed experience. We know that the swiftest race-horse can scarcely ever run more than a mile a minute, nor can he support this speed more than one or two minutes;

but the swallow does this with ease for nine or ten hours a-day. The golden eagle, it has been confidently affirmed, will wing its way through the fiercest storm, at the rate of forty miles an hour. It is well known from actual experiment that sound travels eleven hundred and forty feet in a second, and in all these instances the rapidity of motion is almost incredible; but we must never allow our scepticism to be excited by what at first sight appears to be beyond the range of possibility. A stream of these particles of light, emanating from the sun, or any luminous body, constitutes what is called a ray of light, which at all times proceeds, as long as it meets with no obstruction, in a straight line. Thus we can see through a straight, but not through a bent tube. In aiming with a gun at the bull's eye in the centre of a target, our endeavour is to direct the bullet along the straight rays of light which proceed from that point to our organs of vision, and to enable us to take a surer aim, we generally close one eye in order to exclude all the rays of light excepting those which proceed from the point to which the attention is directed. We accordingly say that a ray of light moves in a straight line; but if it meet with a body, such as a mirror, that interrupts its progress, what is the result? It is unable to proceed directly onwards, and is reflected out of its course as a stone is when struck against a wall, This is called the reflection of light. On a clear summer's day when the sun is shining on the bosom of a lake or river, its rays of light are thus turned or reflected back to the eye, with a brightness so overpowering as to be frequently insupportable. So likewise in walking on the sunny side of the street, the reflection of the rays from the pavement and houses dazzles the eyes, and induces us to take shelter in the shade. On the sandy deserts of Africa and Egypt the continued reflection of the sun's rays from the sand gives rise to painful maladies of the organ of sight. It is for the same reason that when we walk out after a fall of snow, if the noonday sun shines brightly, the number of rays that are reflected from the snow around, causes a painful sensation in the eyes. Travellers who have visited the northern latitudes have complained much of the annoyance they had to endure from this reflection of light from the snow and ice which perpetually exists in those dreary regions. The Esquimaux are not even reconciled by habit to this inconvenience, but are subjected to inflammation and other diseases of the eyes; many persons having, says Captain Lyon, lost their eyelashes and became nearly blind. But if such be the distressing consequences of the sun's rays, it may be asked, how comes it that we ourselves do not experience more annoyance from this cause? By the knowledge conferred on us by science, we are enabled to explain the reason, which is simply this—that while certain bodies do reflect all the sunlight, others take up or absorb it in a considerable quantity, so that only a part of it is reflected. Thus a soft dark earthy soil allows the rays of light to enter into it, and they there remain retained. It is this power which certain bodies have of absorbing light, that prevents our having to walk through a world in which we should otherwise be continually dazzled.

We have thus far alluded very generally to the reflection and absorption of light; but there is another interesting property it possesses, which we will shortly consider, as it gives rise to some of the most beautiful and curious appearances in nature. When a ray of light proceeds through the same medium, we will say the air, it moves in a straight line, and if admitted into a dark room, through a hole in the shutter, it appears white; but if it passes in a slanting direction from a rarer into a denser medium, as from air into water, it is then urged out of the straight line, and appears as if it had been suddenly bent. For this reason, a straight rod or stick, when immersed in water, appears to be broken at the surface of the water, and the portion immersed seems to be bent upwards. The light thus proceeding out of its straight course is said to be refracted, and our observations on objects placed in water are liable from this circumstance to considerable deception. For example, —a deep bodied fish seen near the surface of the water appears a flat fish; a round body there seems oval; and objects seen at the bottom of the water do not appear to be so deep as they really are; from which source of error, judging of the depth of a clear river from the bank, people have been frequently tempted beyond their depth, and, not unfrequently, drowned. Now, we must not forget that light, in passing into our atmosphere, has moved from a rarer into a denser medium—that is, from the thin ether above the highest stratum of the air, into the thicker mass of air which more immediately surrounds the earth. This air is generally loaded with a watery vapour, so that the medium through which light has to pass in our atmosphere undergoes many remarkable changes. Hence the distance, height, and relative position of mountains, hills, valleys, and towns often appear altered. A certain range of mountains in one condition of the atmosphere will appear nearer; in another, more remote from the spectator than usual. But in being thus bent out of its course, a ray of light exhibits a variety of beautiful colours, the cause of which Sir Isaac Newton satisfactorily explains.

We have already observed, that if a ray of light be admitted through the hole of a shutter into a dark room, it appears of uniform whiteness, but Sir Isaac discovered that this white ray of light is a combination of seven different coloured rays, which by a prism (a triangular piece of glass,) may be separated easily from each other. This indefatigable philosopher proceeded with his experiment thus:—he made a hole in one of the window-shutters, and having darkened his room, let in a convenient quantity of the sun's light. He next intercepted this light with his prism, and found that, in passing through the glass, the light was so refracted as to exhibit on the wall an image of several different colours, viz., violet, indigo, blue, green, yellow, orange, and red. "It was at first," says he, "a very pleasing divertisement to view the vivid and intense colours produced thereby:" and we may suspect what might be the feelings of the illustrious discoverer, from what we ourselves have felt on trying the experiment more than once. After varying his experiments in a most ingenious manner, he established this interesting fact, that every ray of white light consists of seven other primary and different coloured rays, each of which seven is more or less refrangible than the other. Sir Isaac having obtained the seven different coloured rays, gathered them again together by the aid of a lens (a glass spherically convex,) and re-produced the white ray of light. Further, in corroboration of this, he mixed together one part of red lead, four parts of blue bise, and a proper proportion of orpiment and verdigris. Then going to the distance of twelve or eighteen feet, so that he could not discern the unevenness of the surface of the powder, nor the shadows let fall from the gritty particles thereof, the powder appeared intensely white, so as to transcend even the paper itself in whiteness. Sir Isaac Newton's discovery, that the combination of these different coloured rays produced the white rays of light, and that each of these elementary or primary rays possessed its own specific degree of refrangibility, revealed at once the explanation of many of the most interesting appearances in nature. Nothing can be more beautiful than the colours with which the tops of mountains, the surface of the ocean, and the different shaped clouds are tinged, at sunrise and sunset, the cause of which now became perfectly plain. The white rays of the sun, entering into an atmosphere of varying density, pass through it like the sunbeam through Sir Isaac Newton's glass prism, and are in a similar way decomposed. The rays that are the least refracted or bent from their course, reach the earth in all the purity and beauty of their own individual colours, and enter into a thousand varied combinations. When the sun is shining in all its noon of brilliancy high above the horizon, its rays, falling on the wide expanse of the ocean, are reflected back unchanged in all their original silvery splendour; but when the sun is setting, and its rays fall slanting on the face of the waters, the red, being the least refrangible of the primary rays, floods with a fiery glow the moving billows, and the line of the visible horizon. Around the heavenly bodies—the sun and the moon—circles of light of the most varying colours frequently appear, which may be explained on the same principle, these halos being nothing more than the rays of light reflected and refracted by the small round particles of vapour through which they pass before reaching the sphere of our vision. But the most familiar instance of the decomposition of light into its prismatic colours is exhibited to us by the rainbow, which is occasioned by the light of the sun shining on the globular drops of water falling in an opposite shower. In this instance the rays of white light are refracted or resolved into their primary rays, which are reflected in the form of an arch across the firmament. Sometimes more than one or two of these arches are formed. Captain Parry informs us that he saw five rainbows at one time, and each complete. Sometimes the arches intersect each other, and they have been seen in an inverted position. Lunar rainbows also frequently occur, but do not display such variety of colours, Rainbows also frequently appear among the waves of the sea, when their tops are buffeted by the winds, and blown into small globules. They appear, too, occasionally on the ground when the sun shines on a very thick dew. The falls of Niagara—and those of less note—even small cascades and fountains, whose waters in falling are divided into drops, display rainbows when the spectator is in a proper position to observe them. But the most remarkable consequence of the refraction and reflection of light is the numerous atmospherical deceptions which are thereby occasioned. Places at considerable distances are sometimes unexpectedly brought within the sphere of vision.

In the Records of the Transactions of the Royal Society of London, we find that in 1788, the coast of France was distinctly seen at Hastings. Towns, hills, valleys, islands, ships, &c., have been seen reflected in the heavens. In the county of Huntingdon, on the morning of July 16, 1820, at half past four o'clock, the sun was shining in a cloudless sky, and the light vapours that arose from the river Ouse were moving over a little hill near St. Neots, when suddenly the village of Great Paxton, its farm-houses, barns, dispersed cottages, trees, and its different grass fields, were clearly and distinctly visible in a beautiful aerial picture which extended from east to west about four hundred yards. Nothing could exceed the surprise and admiration of the spectators as they looked at this surprising phenomeon, nor their regret at its disappearance in little more than ten minutes. Among the Hartz mountains in Germany, at Soutra Fell in Cumberland, in the South of Italy, and in several other places, similar phenomena have been observed. In the Memoirs of the Wernerian Society of Edinburgh for 1827, appears an account of the Skerry Islands, situated in the sea about four miles distant from the coast of Ireland, appearing at an extraordinary elevation, apparently two hundred yards above the level of the sea, breaking off by degrees in the centre into appearances resembling old castles, towers, and spires. Two or three of such images in an inverted position are sometimes seen above the other. In the neighbourhood of Edinburgh, Inchkeith, an island in the Frith of Forth, has been seen reflected in the sky in an inverted position above the island, and above that another picture of it in its natural position. In the northern seas, owing to the peculiar refractive state of the atmosphere, such appearances are of frequent occurrence. When the rays of light fall on the surface of the ice, they are thence reflected into the air above, and often produce an aerial map of the ice and sea below. This is called the iceblink. Nothing can exceed the curious, and at the same time splendid exhibitions, presented by the unequal refraction of the light from the ice and the land in these desolate regions. Captain Scoresby says, hummocks of ice assumed the forms of castles, obelisks, and spires; in some places the distant ice was so irregular, and appeared so full of pinnacles, that it resembled a forest of naked trees; in others it presented the character of an extensive city, crowded with churches, castles, and public edifices. He also records several instances of ships being reflected one above another in the sky, at a time when the ships themselves and the images were so distant as to be recognised only by the aid of a telescope. We have already explained how the rays of light become refracted in passing from a rarer into a denser atmosphere, and the frequency of these appearances in these regions is owing to the varying and unequal density of the atmosphere, which, when moist and warm, becomes chilled and condensed by passing over the extensive surface of ice.

Light produces the most important and beneficial effects on the inanimate and animate creation, and, without its gracious agency all nature would sicken and die. Many substances such as oils, mineral acids, preparations of mercury, silver, lead, &c., change their colour when opposed to light. Those parts of a room which are painted with white lead and oil, and defended from light by furniture, become darker than the rest, but on exposure acquire the same brightness. Plants raised in the open air, when placed in darkness, become pale, and fade in two or three days; those which, after having been raised in darkness, have been exposed for a time to sunlight, cannot support the want of light, but decay. Plants that grow beneath stones are white, soft, watery, and insipid, of which fact many gardeners avail themselves to furnish our tables with white and tender vegetables, by binding up and compressing their leaves together, so as to defend them from the contact of light. The light of a lamp can, although but imperfectly, replace that of the sun. The plant becomes green and inclines to the light; but this artificial light has a more beneficial influence when reflected from mirrors; and hence many hill-sides are rendered peculiarly fertile by the similar reflection of the light. When the sky has been long obscured by clouds, the leaves of trees and grass lose their usual bright green colour. This is corroborated by an American Professor, who says, "Clouds and rain have obscured the hemisphere during the last six days. In that time, the leaves of all the forests which are seen from this place have greatly expanded; but they were all of a pallid hue until this afternoon, when, within the period of six hours, during which we had sunshine, they all changed their colour to a beautiful green."

The entire absence of light is so injurious to plants, that it has been concluded, that without the light of the moon and stars, night would destroy vegetables. The complexion of man, and the colours of different races of amimals, are considerably modified by exposure to light. African ladies, who live much within doors, are not so dark as those persons who spend much of their time in the open air. Animals in the polar regions do not exhibit the variety of colours which those present that are natives of tropical climates. In this country likewise, we observe that foxes, rabbits, hares, &c., assimilate to the colour of the soil they frequent. Birds, too, that fly by night, do not display so varied and gaudy a plumage as those which fly by day. Animals, if totally deprived of light, would, like plants, languish and die. Nothing, indeed, can be more appalling than total darkness; and for this reason, the denunciation of Him who made the sun and the moon is so terrible, which declares that "The wicked shall be cast into outer darkness, where there shall be weeping and wailing and gnashing of teeth."

Having thus explained, in a general manner, the sources, the nature, and the effects of light, we shall now proceed on the same principle—that is, endeavouring to explain everything in the most simple manner, and avoiding as much as possible the introduction of scientific terms—to devote our attention to the subject of

HEAT.

In taking a view of the magnificent theatre of Nature, we at once perceive the vast importance of this agent:—by its power, rocks, islands, hills, and mountains have been upraised out of the innermost depths of the earth;—by its operation, the genial moisture, which, under the form of rain, desends, cooling the heated air, and refreshing the parched-up soil, is raised from the bosom of rivers, lakes, and seas;—by its influence, the waters which were chained up by frost during the desolate reign of winter, are again set free to sparkle along at the bases of their sunny banks;—by its benignant agency, the trees, that were deprived of their foliage, and the herbs that were apparently withered, are again invigorated with new life, and arrayed in new beauty;—it controls and modifies, indeed, life under every form; and is the most universally pervading important agent with which we are acquainted.

When we consider the dreary monotony of the polar regions, where human nature appears in its most humble and degraded form, and where the bears, wolves, and foxes seem alone to find appropriate habitations; and when we compare these trackless solitary wastes with the blooming valleys of sunny Italy, we at once see the vast influence of different temperatures on the surface of the globe; nor do we hesitate to refer such modifications to the sun, which is undoubtedly, the principal fountain both of heat and light. At a period when science was in its infancy, the ancients observed this general fact, and concluded that the sun was an immense globe of fire; but this opinion has long since exploded. The astronomers of our own more enlightened age, have shown by the aid of telescopes of vast power, that the sun is itself a solid and opaque body, perhaps a habitable globe, and they have come to the conclusion that we owe both light and heat to the peculiar atmosphere by which it is surrounded. Although this opinion has been advocated by Sir William Herschell, it must be acknowledged, that the manner and region of the sun in which heat and light are generated, can by no other means be understood, and on this, as on every other subject of inquiry, it is better to confess our ignorance, than to raise up a plausible and satisfactory knowledge. Certain it is, that the rays of the sun do impart heat; but it must be observed, that they do not so unless they come in contact with some solid body—that is to say, they pass freely through the air without giving out any sensible heat until they reach the surface of the earth. Accordingly the higher we ascend in the air the colder it becomes—a fact experienced by those who have ascended in the balloons; several of whom have, on such occasions, found the thermometer sink a great many degrees, even below the freezing point. It is from the same cause that the higher we ascend a mountain, the more intense does the cold become, so that we at length arrive at a region where we can trace no signs of animal or vegetable life, all around being shrouded in perpetual snow. When the traveller ascends the Cimborazo mountain, which forms the extremity of the Andes in South America, and which rises to the height of twenty thousand nine hundred feet above the surface of the earth, he leaves at its base a hot region, where the exhalations of a marshy soil, and the continuance of heat, generate fevers and diseases fatal to animal and vegetable life. Ascending higher, he arrives at a temperate region, which possesses a moderate and constant warmth, and is a perpetual season of spring to those who have arrived from the lower, summer-like, hot region. Above this again, as he ascends still higher, he finds himself surrounded by ice and snow, and then suffers the most intense winter cold, so that it may be truly said, that summer, winter, and spring, are here seated on three distinct thrones, which they never quit, and where they are constantly surrounded by the attributes of their respective powers. Vegetable and animal life present us with equally remarkable gradations, in these regions—thus, the forests of the lower or burning regions are remarkably rich, and they continually resound with the howlings of different tribes of monkeys, and the ant-eater and black tiger prowl about them, while the surronnding air is infested with myriads of mosquitos and other obnoxious insects. Higher up the mountain is found the most splendid palm-trees, upon which the sloth may be seen hanging, and at the feet of which the terrible boa-constrictor and crocodile may be often seen extending their frightful forms. Above this region is met the most beautiful aborescent ferns, and the precious bark tree, and many flowers of surpassing beauty; but here, the air becoming colder, the sensitive plant, as if giving warning of the sterility and lifelessness of the region to which we are approximating, loses its peculiar sensibility, and no longer closes its leaves on being touched. At length, as we ascend higher, the gigantic trees appear to have dwindled; the eye rests on nothing but short stunted and alpine plants, until at last the lichens and mosses amidst patches of scattered snow apprise us that we have arrived at the boundary of organised beings; and that above us is nothing save the dreary region of eternal winter. Here no animal is observed, excepting occasionally the great condor, which is the only living being that appears to inhabit these dismal solitudes. It is obvious that here there is a regular gradation of temperature from the surface of the earth to the upper regions of the air; and for one hundred and ten yards of ascent, the heat diminishes as much as if we were to advance one degree of latitude towards the northern polar regions. The facts here described are of the utmost importance, because from these we observe that certain parts of the world are rendered not only habitable, but possess a fine and genial climate, which would otherwise be parched up by a tropical and burning sun. For example the city of Quito is almost under the equator, and were we to form a superficial judgment of its temperature from its situation, we might conclude that it would be oppressed with intolerable heat, instead of which, owing to its elevation, the air of that city differs little in temperature from that which we find in Paris.

It is, therefore, obvious that the rays of the sun do not produce heat unless they strike upon some solid body, and even the greater or lesser intensity of the heat they produce is greatly modified by the direction which they take, for when these solar rays fall directly or vertically on a particular district, they give out much greater heat than when they fall obliquely. The reason for which is simple; when they descend upon a spot directly, they fall on it with much force, and a great number of them are included in a small space; whereas, when their direction is more slanting, they not only do not strike the spot with the same force, but are more scattered, so that they by no means produce the same intensity of heat. By this general fact, then, we are enabled to explain the diminution of temperature from the equator to the poles—that is from the tropical to the frigid regions. Near the equator we find a zone, which passes immediately under the sun twice a year, and receives its rays in a very direct or vertical manner; and here we have the tropical region. Next, we find a portion of the globe, which does not receive the sun's rays so directly, but, on the contrary, more obliquely, so that less heat is produced, and here, therefore, we find the temperate region. After this we reach another region of the globe, which is altogether deprived of the heat of the sun for the greater part of the year, and, during the other receives its rays still more obliquely; and here, consequently, we have the frigid zone, that desolate region of eternal ice and snow, which has been explored in vain by so many intrepid navigators. This variety of temperature, occasioned by the different direction which the sun's rays take in reaching the earth, is remarkably obvious in hilly countries. If a hill, having a southerly aspect, present a certain inclination, and the sun be at a corresponding altitude, the solar rays will strike the side of the hill perpendicularly, while on the plain below and around, the rays strike the earth obliquely, and with a proportionate diminution of force. If the ground extend to the north, it will receive no rays, and remain always in shade; and it is on this account that in the Valais we see the Alps on one side covered with eternal ice, whilst the opposite hills are adorned with rich vineyards, and orchards, and all the charms of fertility. Nor is the different manner in which the rays of the sun strike the earth the only circumstance to be considered in examining the temperature of different climates; for the rays of heat, like the rays of light, undergo a greater or lesser reflection; that is, when they strike the earth they are thrown back into the atmosphere, and are more or less confined and diffused among the watery vapour with which it is always loaded. Hence arises the warm and genial temperature which surrounds the immediate surface of the earth, and which is so admirably adaped to support animal and vegetable life. Some soils likewise absorb the sun's rays more than others; thus a moist clayey soil takes up and retains the rays of heat for a considerable time; a dry sandy surface, on the contrary, immediately reflects them; and thence it is that the traveller, in journeying through the sandy deserts of Africa, experiences the most oppressive and almost intolerable heat. This is aggravated by the dryness of the air, for when it contains much moisture, as is the case over marshy soils, the heat is considerably diminished; but such marshes in hot countries undergo fermentation, and give rise to exhalations that produce the most pestilential diseases. The vicinity of the sea also very considerably moderates the effects of temperature; and on this account the interior of continents is colder than their coasts. So intense is the cold in the mountains of Norway, that it proved fatal to most of the Swedish army during the war, the dead bodies of the soldiers having been found in great numbers; but those who live on the coasts of that country enjoy a very mild and agreeable climate. When the sun's rays fall on the surface of the water, part of them enter it, and the continual motion of the waves, presenting a cool and fresh surface to the heated air, it is cooled, so that, while the land air is heated, and rises up into the upper regions, a cool sea breeze springs up and rushes in to supply its place. The vicinity of the sea, therefore, moderates the heat of summer. It is also well known that the temperature of water is always more equalised than that of land, and, consequently, in winter, when the sun's rays fall very obliquely on the earth, and its surface is covered with snow which prevents the heat of the earth radiating into the air, the sea, having a more uniform temperature, continues to radiate heat, and thus a warmer region of air is formed, which modifies the cold of winter. On this account, at Plymouth, although the mean heat of the year is, on the whole, a little less than at Paris, the winter months are much less severe. Also, in the coldest winter months, the temperature of Edinburgh is some degrees warmer than that of London. From what we have stated, it must appear obvious that, while we regard the sun as the principal source of heat, yet the heat is modified by the direction which the solar rays take in reaching the earth, by the reflection and absorption which they there undergo, and by the vicinity of the sea.

We have as yet only considered the heat produced on the surface of the earth by the direct and immediate action of the sun; but, independent of this, we have conclusive evidence of the existence of very intense heat in the central depths of the earth. In descending into deep mines, the temperature of the air has been found to increase as we go down, but the presence of the miners, the lamps they use, and the explosions of gunpowder, render many such experiments very erroneous. Other methods, therefore, have been adopted to examine into the truth of the supposed fact, such as boring and cutting niches into rocks, taking at the same time every possible precaution against all sources of fallacy. The result has still been the same, and leads to the conclusion that a very great heat exists at a depth of the earth beyond the sun's influence. The hot springs, which abound not only in volcanic districts, but in various other parts of the world, also lead us to the same inference. The most remarkable springs of this kind are found in Iceland, where the principal one is called the Geyser, situated in the middle of a plain, and surrounded by forty other springs of a smaller size. These throw up their waters to a very considerable height. The eruption commences with short jets, which gradually increase in size; the steam then rushes forth furiously, accompanied by a loud thundering noise, resembling the distant firing of artillery from a ship at sea, until at last a great mass of water is raised to a height of seventy, eighty, or ninety feet. The Icelanders use the more temperate of these springs as warm baths; in those that are hotter or boiling, they boil their various articles of food, taking only the precaution to cover the vessel used to prevent to volcanic odour giving a taste to their food. Volcanoes are also unquestionable proofs of the existence of this subterranean heat, which must exist at a considerable depth in the earth, because rocks, which are well known to have their original position at such depths, are, during their violent action, ejected into the air actually liquified by heat. Some of those volcanoes seem to have exhausted themselves and have become extinct, examples of which are to be found in the central parts of France and Germany. Others exist in a state of frequent or continual activity, such as Vesuvius, Ætna, Stromboli, and Hecla. Besides which, we are aware, that owing to violent volcanic action, immense rocks are forced up from a considerable depth, even from below the surface of the sea, and so form islands. In July of the year 1831, an island of this kind arose in the

Mediterranean. The water was at first violently agitated, after which vast quantities of smoke and steam were evolved, and enormous masses of hot cinders, dust, &c., ejected several hundred feet into the air. Captain Steunhouse landed on this island the following month, and estimated its circumference to be about a a mile and a quarter. It is supposed that rocks so formed are of igneous origin, and of such rocks there are numerous examples in the immediate neighbourhood of the city of Edinburgh. In examining either of which it is at once perceptible how these igneous rocks have rent asunder and forced their way through superincumbent strata, now filling up the immense crevices they have torn open, and now overrunning the whole subjacent mass. When these vast and powerful operations of nature took place, terrible and sublime, indeed, must have been the convulsion exhibited, and altogether beyond the range of the human imagination.

From what has been stated—from the temperature increasing in the deeper parts of rocks and mines—from the existence of hot springs in various parts of the world—from the phenomena exhibited by volcanoes, and the appearances of rocks that have visibly undergone a state of fusion, we are entitled to believe in the existence of heat as a most important agent beneath the surface of the earth ; and whether it arise from central fire, or whether it be generated by some remarkable chemical actions that are in progress, has not as yet been satisfactorily determined.

But in taking this general survey of the sources and influence of heat in nature, we ought not to forget, that it is frequently seen to arise from electricity. Even in Great Britain, where thunder-storms are neither so frequent nor so violent as in many other parts of the world, nothing is more common than for lightning to melt metallic substances, especially iron. In a great thunder-storm that happened in Herefordshire, a few years back, the thick band of iron that was used to support a wooden railing in a field adjoining to the city of Hereford, was completely melted between each piece of wood—a fact which at once shews how intense the heat must have been. In Italy, where such occurrences are not so rare, previous to the removal of the remains of the celebrated poet Ariosto from the Benedictine church to the Library of Ferara, his bust, which surmounted the tomb, was struck by lightning and the crown of iron laurels melted away. Lord Byron has recorded the circumstance, in the following stanza in the fourth canto of "Childe Harold:"—

"The lightning rent from Ariosto's bust
The iron crown of laurels' mimic leaves,
Nor was the ominous element unjust—
For the true laurel leaf which glory weaves
Is of the tree no bolt of thunder cleaves,
And the false semblance but disgraced his brow;
Yet still it fondly superstition grieves.
Know that the lightning sanctifies below
Whate'er it strikes. Yon head is doubly sacred now."

When we take into our consideration the operations of heat on the capacious and splendid scale of which they really take place in nature, it may readily be supposed that man would be led, even before the sun of science shone upon the world, to contrive some plan for procuring that peculiar modification of light and heat which constitutes fire; nor is it to be wondered at, that so many remarkable superstitions were attributed to it by the ancients. It is generally well known that the Persians worshipped fire. The patriarchs used it in ther burnt-offerings; it was kept constantly burning in the Jewish tabernacle, and was regarded as the origin of life, the soul of the world, and the visible symbol of the Deity. We have already explained how it has been procured artificially by friction, as well as by concussion, and likewise stated that it might be kept up by the burning of inflammable bodies, which is called combustion. The compression of the particles of bodies nearer to each other is always more or less attended by an evolution of heat; and this is the case with air; for if a quantity of air be confined in a syringe, in which there is a piece of tinder at the bottom, and then violently compressed, sufficient is produced to ignite the tinder. It has also been shown by a member of the Academy of Paris, that water itself, when submitted to a pressure of twenty atmospheres, gives out a certain quantity of heat. But it may be asked what is the nature of heat? of what does it actually consist? We shall simply reply that there are two opinions advocated; the first, that heat consists of nothing more than a certain vibration of the particles of the hot body; the other that it does not consist of any such vibration, but is itself, an independent substance, being an extremely subtile and elastic fluid, contained and dispersed among the pores of matter. This latter opinion appears to be the most plausible, and among reasons for thinking so, we may state the following two: the first is, that the addition of heat to a body increases its bulk, leading us to suppose that it receives some addition; the second is, that bodies throw out their heat to a considerable distance, which could scarcely happen unless the heat so solved was distinct, and independent of the body itself whence it proceeds. Heat, therefore, we conclude, is a very subtile and elastic fluid; but we may here mention, that some philosophers consider light and heat are only modifications of each other, and this opinion has been very ingeniously supported by Sir John Leslie, of the Edinburgh University. Whatever be the abstract nature of heat, its accumulation in, or abstraction from different bodies, gives rise to the most remarkable changes; a few instances of which we will introduce as we proceed in our description of *The Properties of Heat, and its Effects.*

Without heat the earth would not pour forth its numerous streams, nor be clothed with verdure—nor would the air be refreshed with genial moisture—neither would the humblest of living beings be enabled to support its own bare existance.

We have said that heat is a fluid, because, like all fluids, it has a tendency to seek its own equilibrium, that is to say, to distribute itself equally in every direction. Suspend a ball of iron, red hot, in an apartment, and the heat from it disperses itself equally through the cooler air, until one temperature pervades the ball and surrounding air. A fire placed in a grate diffuses its heat equally until every object in the room arrives at the same temperature. And well it is so; as were it not for the tendency of heat to equalise its distribution, it would accumulate in large and irregular quantities, and we should be exposed to the most painful transitions, and hurried continually from the most excessive heat to the equally intense agonies of the extremest cold, like the unhappy spirits described by Dante and Milton—

"Thither by harp-footed furies hurl'd
From beds of raging fire, to starve in ice."

Heat therefore seeks its own equipoise; it also enters in greater or lesser quantities into the pores of all bodies; but do some not allow it to pass through them so readily as others. If we place one end of an iron rod in the fire, the heat passes so quickly through the whole length of the rod that in a short time we cannot touch the other end without being burnt; but we may hold one end of a short stick in our hand while the other end is actually blazing, so slowly does the heat pass through the substance of the wood. Metallic vessels, used for containing hot fluids, require wire, bone or wooden handles, which being very slow conductors of heat, interrupt its communication to the hand. Those bodies which allow heat to traverse through them very quickly, are called good conductors —those that retard its progress, bad conductors of heat; and it has been found that the densest bodies are the best conductors. Silver, gold, copper, iron, allow heat to traverse them more readily than glass, wood, porous earths, and bodies of a looser texture. Fluids, owing to the mobility of their particles, receive and transmit heat better than solids; hence when a hot body is plunged into water, it cools more quickly than if it were plunged into a mass of sand. Air is is not a good conductor of heat, which is another admirable provision; for if it allowed its transmission as readily as the metals, the heat from the surface of the earth would be so speedily carried away, that nothing would be able to support life. But it has been discovered that air in a state of absolute rest, does not conduct heat at all;— and this is a fact of the greatest importance. On a hot summer's day, when there is scarcely a breath of wind stirring, the oppression we feel is in a great measure owing to this cause, for we are then moving in an atmosphere which does not carry away the accumulating heat of the body. Furs, wools, feathers, and loose spongy substances, are bad conductors of heat, for the air which is retained between their interstices, and which are at rest, prevents its transmission through them. Such materials are therefore chosen for winter clothing, not, as is the general idea, because they contain or impart any heat, but simply because they prevent its escape from the body and protect us at the same time from the external cold air. Thus protected, many of our boldest and most intrepid navigators have braved the winter of the polar regions, and lived with impunity amidst the coldness of those desolate solitudes, which seem to place an eternal barrier against the further extension of human knowledge or of human dominion.

Prodigal in her beneficence, Nature has provided an appropriate and adequate covering for the animals of the different regions on the face of the globe. Those living in hot countries have the hair of their coats fine, thin, and short; in those again that frequent more temperate climates, their hair becomes thicker and woolly; while those in the coldest countries, in high latitudes, their coats become shaggy, coarse, and thick. Animals that live much in water, are provided with the finest, longest, and thickest furs; and in all instances the fur is thicker on the parts of the body most exposed, more especially on the back, because the heat escaping upwards, requires a greater obstruction in that direction. Birds frequenting the higher regions of the atmosphere require not only that their bodies should be light, but well protected from the cold, which, as we have already explained, increases as we ascend into the higher regions of the air. We find that Nature has not been unmindful of these requirements; for in these birds the body is not only rendered light, by their bones being hollow, and communicating with the lungs, so that they are always filled with air, but they are enveloped in a manner which does not allow their natural heat to be easily carried off; their plumage, also, so beautiful to the eye of the spectator, is likewise an admirable protection against cold, for the quill, shaft, and web of the feather are so constructed as to offer the necessary obstruction to the escape of heat. The feathers, too, vary in kind and quantity, according to the habits of the bird, the climate it inhabits, and the season of the year. But there are animals destined to live in the northern seas, which are exposed to a much more intense degree of cold, yet which are not protected either by feathers or furs. They are, however, provided with an equally efficient defence, for under the skin, disposed in small cells, large quantities of fat, or thick oil are imbedded, which completely envelopes the whole body. Such is found in the whale, the seal, and the walrus; and the oil that is thence produced is well known to be a very important article of commerce. In all these instances, and numerous others needless here to mention, such coverings operate simply as non-conductors of heat; preventing at the same time the escape of the natural warmth of the body, and the penetration into it of the external cold. Man, taught by observation and experience, has taken advantage, as already remarked, of these facts, to supply himself with winter clothing; and according to experiments made by scientific men, it appears, hare-fur, and eider, down are the warmest materials for such apparel; after beavers' fur, raw silk, sheep's wool, and cotton wool, and after them lint, or the scrapings of fine linen.

From what we have stated, we presume that it is understood that heat has at all times a tendency to distribute itself equally in all directions, and that some bodies allow it to pass through them more readily than others: which facts will now enable us to understand the cause of our sensation of heat and cold. When several bodies of equal temperature are placed together, they each give out and receive the same quantities of heat, so that there is no increase of the temperature; but when bodies of different temperature are placed in contact with each other, the hotter gives out heat to the colder body, until the same temperature is established between them; — for example, when the hand takes hold of a body colder than itself, it becomes sensible of cold, because a portion of its heat is conducted away by the colder body; but if it grasp a body that is hotter than itself, then the body of higher temperature communicates to the hand, which becomes sensible of warmth. In all these instances the intensity of the sensation depends on the superior or inferior conducting power of the body grasped, for the more rapidly the heat is carried away from the hand, the more intense is the sensation of cold thereby produced. The carpet in a room of usual temperature, feels nearly as warm as the hand; the table feels rather colder; the marble chimney-piece colder still; and the fire-irons coldest of all; but each of these will, on the application of a thermometer, be found of the same temperature, and the difference of the sensation is produced only by the greater or lesser rapidity with which they severally conduct away the heat from the body. Our sensations of heat and cold, therefore, are merely relative; for even ice, when carried into a room, the temperature of which is below the freezing point, will radiate heat. Snow appears cold to a healthy hand; but it is frequently applied to frost-bitten limbs, because it is warmer than limbs so affected; the object being to apply heat in the most gradual manner. Two persons bathing, will, according to the heat of each, find an apparent difference in the temperature of the same stream. A person from India arriving in England, in the spring season will complain of coldness, although the inhabitants in that country are beginning to cast aside their winter apparel. The great danger which arises from going out of a heated ball-room or a theatre, is occasioned by the transition of the warm body into a colder atmosphere; by which many lives are annually sacrificed, as it were, on the shrine of pleasure; and the seeds are sown, by which the fairest, and the loveliest of the land, fall victims of lingering consumption.

Heat is an agent of so subtle and diffused a nature, that we have not discovered any kind of matter that is totally destitute of it, and its accumulation, or abstraction, in various bodies, must necessarily effect great changes in them. It is a well-known fact, that the solid particles of all solid bodies are held together by a power of attraction which they exert among themselves, and which is called the attraction of cohesion, or aggregation; but no two particles of matter are ever in actual contact. Interstices of greater or lesser magnitude must exist between them; and it is into these that heat insinuates itself. It is evident, therefore, that heat must produce expansion; for, by accumulating, it must stretch these spaces, and force particles bounding them to a greater distance from each other, whereby the whole body must necessarily be increased in bulk. But as this accumulation of heat causes an increase in the size, so must its abstraction, by diminishing the size of these openings, and allowing the surrounding particles to approach nearer to each other, occasion the contraction of a body.

A few examples will suffice. An iron bar, when heated, cannot be made to enter an opening which, when cold, it will readily enter; of this fact coachmakers and others avail themselves. In making carriage wheels, they place the iron rim round the wheel while red-hot; then as the iron cools, it contracts and embraces more firmly the wooden portion of the wheel. Even in this country, the heat of summer is sufficient to occasion the most remarkable changes in the condition of metallic bodies; for instance, the centre arch of an iron bridge is higher in hot than in cold weather; the gate of an iron railing, which during cold weather will open and shut easily, will sometimes stick fast on a warm day, owing to there being a greater expansion of it and the adjoining railing than of the ground in which they are fixed. The pitch of a pianoforte or harp is lowered during a warm day; and although tuned in a morning, will become out of tune if the same room be heated by a crowded party, owing to the expansion of the strings being greater than that of the frame-work of the instrument. Buildings of considerable size and strength have been very often much injured by the expansion of the iron bars fixed in different parts of them; a case of which kind happened only a few years since to Bow Church in London. In this church, the bars of iron, used to hold together its fine steeple, expanded during summer, and forced the stones sufficiently apart to allow dust and sandy particles to lodge between them; nor is there any doubt but that had it not been repaired soon enough, the whole edifice might have fallen. A very curious experiment upon the known expansion of metals by heat, occurred some time ago in Paris, at the Abbey St. Martin, afterwards called the Conservatoire des Arts et Metiers. The immense weight of the roof of this building was forcing the walls asunder, when they were restored in the following ingenious manner, to their perpendicular position:—Holes were made at opposite points in several places in the walls, through which strong iron bars were introduced, so as to extend across the building, and their extremities beyond the walls. Large nuts were then placed upon their ends, and screwed up so as to press upon the walls. Every alternate bar was then heated by powerful lamps, so that its length increased by expansion, and the nuts, before in contact with the walls, retired some distance from them. The nuts were again screwed up to the walls, and the iron bars, on cooling, contracted, and from the pressure of the nuts, the walls were drawn together so as to be restored to their proper position.

It must now be obvious to every reader, that the first effect of heat is the expansion of the body into which it enters; and when a still further quantity is added, another change is produced, and the body, however dense it may be, is converted into a liquid. Silver, gold, lead, iron, tin, and all substances with which we are acquainted, may thus be liquified, excepting the diamond, which, being a combustible body, catches fire at a low temperature. The most remarkable circumstance attending liquifaction is this

—when a body changes from a solid to a liquid, or from a liquid to a vapour, its expansion causes a sudden increase of its capacity for heat, in consequence of which it absorbs an additional quantity, which becomes fixed, and so concealed as not to affect the thermometer. This is what is termed *latent* (secret) *heat*. It is this addition of heat which occasions the body to pass from the solid to the fluid state; and thus, when ice is converted into water, it absorbs as much heat as it would, if it did not melt it, raise its temperature 140 degrees. On the other hand, before water can be converted into a solid state, it must, after being reduced to 32 degrees, part with this 140 degrees of heat, which occasioned it to exist in a fluid form. This is the reason that the processes of freezing and thawing are slow operations; were it otherwise, the cold of a single night might freeze an ocean, and the heat of a single day convert the accumulated snows of winter into a sudden and frightful inundation. When water has been heated in an open vessel to the boiling point, instead of its temperature increasing, the additional heat escapes in the form of steam, and this steam absorbs 1000 degrees of heat which immediately becomes insensible. This is the reason, that when water is thrown upon a raging fire, it so powerfully represses it, that the heat enters so rapidly into its latent state in the conversion of the water into steam, that it is soon abstracted from the burning body.

It is now understood, that after expansion, the next effect of heat is to produce liquifaction; but if the heat be still continued, the material particles being forced to a still greater distance from each other, the liquid enters into a state of vapour. Water affords a favourable example of this, being easily vapourised; indeed it undergoes spontaneous evaporation at very low temperatures; but, on the application of cold, the watery vapour is immediately condensed. When steam is first formed it is invisible, as may be observed by noticing it issuing from the spout of a tea-kettle; but when it comes into contact with colder air it is condensed, and assumes the appearance of a visible cloud. An immense quantity of water is incessantly evaporating from the surface of the earth. The fields and roads are inundated after a heavy fall of rain, but the water soon disappears during a little subsequent fine weather. Many large rivers issue into the Mediterranean sea; still it never increases in size, owing to the continual evaporation from its surface. The water thus evaporated from rivers, lakes, and seas ascends into the air, and becomes condensed into clouds. In this country it is seldom that the sky is perfectly transparent; but often on a clear day, we may observe a cloud suddenly formed by a cold current of wind in the upper regions of the air, which rapidly condenses the watery vapour there into light fleecy clouds. We may also add here, that water does not evaporate so quickly when still as when agitated by a brisk wind; for this reason, variable winds are generally regarded as the precursors of rain, and more rain falls during spring and autumn than during summer and winter.

When a body has absorbed a certain quantity of heat, it distributes it forth again; and in so doing, the heat passes off from its surface in straight lines. When a solid substance is interposed, however, the rays of heat are intercepted, as is the case when we use a hand-screen to protect the face from the heat of a common fire. Several curious experiments have been made on this subject; and it has been found that a rough and dark surface projects heat better than a smooth and polished one, so that metals do not radiate heat so well as other substances. Were it not for this radiation, the earth which has been absorbing the sun's rays for many days, would become parched up by the accumulation of heat; instead of which, when the sun has set, it again radiates it forth into the surrounding air. The consequence of this is, that the surface whence this radiation takes place becomes colder than the atmosphere which encompasses it, and condenses the visible vapour which the air always contains into dew. Dew, we may remark, is only deposited on those substances that are below the temperature of the air by which they are surrounded; and as fibrous substances radiate heat best, the dew appears in greater abundance where it is most wanted, on the grass of open plains rather than on bare earth, rocks, and masses of water. It is well known that dew is deposited most liberally on a fine clear night, and but little is produced when the sky is overcast with clouds—the reason of which is, that the clouds, acting like a concave mirror, reflect back the radiated heat to the earth's surface, and so tend to keep it warm. Snows act in the same manner; and by obstructing the radiation of its heat, keeps the earth below warm, while the air above is many degrees below the freezing point. Our own bodies radiate heat. When we go out into the open air at night, this radiation of heat induces a sensation of cold; and the coldness we experience is most intense when we are in an open country in a clear calm night. When it is cloudy the heat is reflected back to us; and even in towns, the reflection from the houses affords to us some compensation; but in the country, when the night is clear and calm, this radiation proceeds without interruption.

ATTRACTION.

THIS word betokens that power by which all kinds of matter, whether of the size of atoms or of worlds, are drawn towards each other. Perhaps, there is no law of nature which produces phenomena so universally and continually presented to our observation as attraction. If we lift our eyes to the starry heavens, and observe the "mystic dance" of those shining orbs, we find it like an invisible rein curbing them in their amazing journeys through the trackless ether, and compelling them to deviate from the straight forward course in which they would otherwise run, and wheel in a circular manner round some other body, the centre of their orbits of motion. Or if we turn our attention to the globe we inhabit, we find it drawing down to the earth the stone which we have thrown into the air; or we see it forming into a globule the little drop of dew which hangs like an appropriate gem upon the delicate leaf of a flower. Or we see two contiguous drops upon the same spray, when brought near to each other, but still situated at a distance sufficient to be discerned by the eye, at last rush suddenly together and become one. Or we may detect its operations in uniting a few simple substances in various proportions, and producing the wonders of vegetable organization in infinite variety and never-failing sympathy! How sublime, yet how simple; how minute, yet how comprehensive and magnificent is this law! at once exercising a power over the smallest atoms around us, while it is, at the same time, determining the revolutions of the gigantic and innumerable orbs that roll throughout the universe; a height and a depth, a breadth and a length of existence, which imagination, in vain, attempts to picture, or reason to calculate. Or, as Rogers justly observes:—

"That very law which moulds a tear,
And bids it trickle from its source,
That law perceives the earth a sphere,
And guides the planets in their course."

This law is indispensable for the preservation and existence of the present order of things; and it would not be difficult to show, that the suspension of it, even with respect to a single star, would in course of time, spread disorder and anarchy throughout the universe. But its invariable operation is the certainty of destiny. Without this unchangeableness philosophy would only be a doctrine of chances: but eclipses for thousands of years to come, for instance, (supposing our world was to remain for so long,) can be calculated upon without fear of mistake, almost to the beat of a watch.

The subject of attraction naturally separates itself into two grand divisions. There is first, the attraction which is exercised by masses of matter, situated at sensible distances from each other; and secondly, the attraction existing amongst the atoms constituting these masses, which takes place at insensible distances. These two divisions are again subdivided, the former into the attractions of gravitation, electricity, and magnetism; and the latter into those of aggregation or cohesion, and chemical attraction or affinity. Many philosophers have supposed, and with some degree of plausibility, that all these varieties depend upon some ultimate power of matter, and may thus be reduced into one; yet has no conclusive argument has been brought forward in support of this supposition, it is needless to take up the time of the reader with ideal speculations, even allowing that they may be correct.

By gravitation is meant that power which draws the objects of the universe towards each other. The sublime genius of Newton, it is said, conceived the idea of universal attraction, from the simple incident of an apple falling from a tree in his garden. May not, he reasoned, the power which draws this apple to the ground with unerring certainty, be the same as that which regulates the movements of the celestial systems? And so, following up this idea, he made a series of discoveries the most brilliant that ever adorned the annals of philosophy. He proved satisfactorily that what we term *weight* is nothing more than an instance of universal attraction, which decreases in intensity as we recede from the earth in distance. This, of course, suggested the idea that weight must be less on the tops of mountains, and in balloons, than on the sea shore, or on plains, which is the fact. What weighs a thousand pounds on the sea shore, weighs five pounds less at the tops of mountains of a certain height, as is proved experimentally by a spring-balance; and at the distance of the moon, the weight or attraction towards the earth of a thousand pounds is diminished to five ounces. This has been proved by astronomical tests.

It may be necessary, however, before proceeding farther, to inform the reader of the manner in which gravitation operates on its amplest scale, in regulating the movements of the unnumbered orbs which compose the system of the universe. All bodies have a tendency to continue in the state of *motion* or of *rest* in which they are put. In other words, bodies do not acquire motion, nor lose motion, nor change the kind or degree of their motion, unless some force or another be applied to them. This property, as it may be termed, is called in scientific language, the *inertia* of matter. For instance, when an arrow is shot from a bow, it would proceed onward through the infinity of space to all eternity, if some force did not curb its speed, and finally draw it to the earth. And what power is this? Plainly, that of attraction. Besides, there is the resistance which the air offers to every body heavier than itself passing through it. Now, space originially was a vast vacuity, we shall suppose, in which there being no matter, there could exist none of the laws of matter. When the Divine Creator brought into existence our own system, to take a familiar instance, he placed the sun in the centre, and endowed it, so to speak, with power and authority over all the other bodies within its range; they were compelled to pay obeisance to it like the surrounding sheaves to the one in Joseph's dream. The lesser or subordinate orb, may be supposed, for the sake of illustration, to have been hurled from the plastic hands of the Deity in a straightforward course, in which they would for ever have moved had not the sun possessed the power of attracting them to its centre, and compelling them to revolve round him. There was just as much attraction given as would keep them in their proper orbits of motion, and just that degree of impetus imparted which would prevent them from coalescing with the sun on the one hand, or departing beyond the sphere of his attraction on the other. With what wisdom, yet with what simplicity, have not the "worlds been framed." To each of them the Creator has traced out its course. "Thus far shalt thou go and no farther." And they cannot for a moment cross the boundaries He has assigned.

"Lightnings and storms his mighty word obey,
And planets roll where He has marked the way."

To this principle we are also indebted for the flux and reflux of the tides, which, as is well known, are caused by the moon's attraction.

"For the moon through heaven's blue concave glides,
And into motion charms the expanding tides;
While earth impetuous round her axle rolls,
Exalts her watery zone, and sinks the poles."

It is also the cause of the roundness of our earth, of the moon, the planets, and the sun itself. Hence it may be inferred that originally all matter was, to a certain extent, in a fluid state, and that at the divine command the atoms were endowed with attractive qualities, by which they were impelled to a common centre; and thus the congregated masses assumed a globular form. At New South Wales, which is situated nearly opposite to England on the earth's surface, planets hang and stones fall towards centre the of the globe just as they do here. And the people there are standing with their feet towards us; hence they are called our antipodes. A plummet suspended near the side of a mountain will be attracted to it in a degree exactly proportioned to its magnitude. This fact was ascertained by Dr. Maskelyne, near the mountain of Shehallion, in Scotland. But the plummet was not so strongly attracted to the mountain as it was to the earth, because the magnitude of the latter was so much greater than that of the former. Let it always be kept in view that it is size, in connection with distance, which determines the force of gravitation, and this may be illustrated by a few familiar facts.

A falling body receives fresh velocity every moment of its descent, while a body projected into the air loses velocity every moment of its ascent. Both propositions are illustrated by a very simple experiment. Sling a stone into the air, and the eye will be found incapable of following it till it has reached a certain height, when we can easily observe its progress. Upwards it rises slower and slower, and for a moment before it has reached, and after it has passed, its climax, there is scarcely any motion perceptible; just as the tide at the full appears for a moment neither to ebb nor flow. Downwards the stone descends, however, gathering fresh velocity in every inch of its declination, until, as it approaches nearer to the earth, the eye can scarcely follow it. This may, no doubt, be partly accounted for from the well-known circumstance, that, to the eye, bodies seen at a distance seem to move slower than they do when we stand near to them. But, in our calculations, the fallacy arising from this circumstance is comparatively trifling. The propositions have not only been proved by the most incontestible philosophical experiments, but a few familiar facts, when called to memory, will settle the point. Let a ball drop from the hand, and it can be caught easily the first instant; let it accumulate its motion, however, and the hand in vain pursues it. Take an example on a larger scale—say, the cataract of Niagara. Slowly and heavily the broad column of water bends over the precipice. It grows thinner and thinner, while its motion rapidly increases, until it last it plunges down the deep descent into the boiling gulf below, with irresistible force and rapidity, carrying all before it, and

"Rivalling the lightning's glance in ruin and in speed."

All bodies, whatever their size or weight may be, should, from the law previously laid down, fall to the ground with the same speed. But this is found not to be the case. Here, for instance, is a ball of lead and a ball of cotton, dropped from the same height at the same moment, and the lead has reached the earth some time before the cotton. At first sight this would really appear to be quite consistent with the law of Nature; because there being, we shall say, a hundred parts more matter in the lead than in the cotton, it will be drawn to the earth with a hundred times more force, the power of gravitation being always proportionate to the quantity of matter. But again, if there be a hundred parts more matter in the bullet than in the other body, it of course requires a hundred times more attraction to bring it down, for bodies destitute of this quality, as has been frequently observed, have no tendency to fall; and every atom of every description of matter is drawn to the earth with the same degree of force. What is it, then, which prevents the cotton from reaching the ground at the same moment with the weightier body? The resistance of the air. The bulks are equal, and of course the resistance offered to both is alike, but the one having a far greater number of atoms, and hence a far greater power of attraction in proportion to its bulk than the other, it overcomes the resistance with greater ease, or, in other words, it has far greater strength to expend with only the same obstructions to overcome, and hence it reaches its destination sooner. For illustration's sake, let us suppose there are two boats to start for the same goal. They are of equal size, and of course their bows present the same breadth of surface to the water, and are alike impeded by it. In the one boat there are two rowers, we shall suppose, and in the other six. They all pull with equal skill and power, and it is unnecessary to say which boat will reach its destination first. But suppose the boat which had the smallest number of rowers were to be reduced in size, weight, and resistance, in a proportion which exactly counterbalanced the power which the other had over it, they would both arrive at the same time. Thus, if the cotton ball was reduced to the density of the lead, they would both reach the earth at the same time. The powers of attraction possessed by the two substances, without attenuating our simile to an invisible thinness, may be compared to the physical energy exercised in the two several boats, and though the comparison be not perfect in some respects, it is sufficiently so in others to give a forcible illustration of the subject. In fine, it is found that in the exhausted receiver of an air-pump, that is, a glass vessel deprived of its air, a feather and a guinea fall to the bottom at the same instant. It would not serve the end contemplated, were the subject of gravitation to be pursued through all its labyrinths, and demonstrated by mathematical symbols. The point aimed at is rather to awaken a desire for philosophical study, than altogether to supply the materials of it.

Very little need be said here respecting the *magnetic* and *electric* attractions, as they are more fully discussed under the titles *Magnetism* and *Electricity*, in another part of this volume. They act on certain bodies, or undor peculiar circumstances, giving rise to a distinct class of phenomena. In so far as they operate on masses of matter at sensible distances, they coincide with gravitation. When certain bodies are submitted to friction, they exhibit electrical attraction. If a dry glass rod, or a stick of sealing wax, he rubbed upon a piece of silk, and then presented to light bodies, such as bits of paper or straw, these latter are attracted to the other body. With respect to the magnet, it is universally known that it possesses the property of attracting steel. Its undeviating tendency to turn to a certain point of the earth is also well known. No phenomena of Nature has been more frequently pressed into the service of poetry, in the shape of a simile, than this. What poet for the last two hundred years has not used it?

"The obedient steel with living instinct moves,
And veers for ever to the pole it loves."

It is unnecessary to enter more particularly into these subjects at present, for the reason given above.

We shall now turn to the other grand division of the subject, namely, the attraction exercised between particles of matter situated at short or insensible distances from each other. Cohesive attraction is that power which retains atoms of the same kind together in masses. When two drops of the same sort of liquid are placed near to each other, as was remarked at the beginning of this article, they attract each other, and uniting together, form one globule. The roundness of the drop is caused by this attraction. The poet Drummond remarks this:—

"Hast thou not seen two pearls of dew
The rose's velvet leaf adorn—
How eager their attraction grew,
As nearer to each other borne."

If two globules of quicksilver on a smooth surface be brought near to each other, they will unite in a similar manner. They have also a tendency to remain in that state, and will not separate until some force be applied. Cohesion is strongest in solids. For instance, a bar of iron of half an inch in diameter, or even less, will defy all our efforts to break it with the hand. In fluids the power is a great deal weaker, as is proved by the ease with which we can separate one portion of water from another. Small needles, however, can be made to float on water, their weight not being sufficient to overcome the cohesion of the fluid. In the same way small insects walk on the surface of water without being wetted. In gaseous bodies, such as air, this attraction is entirely overcome, and a mutual repulsion exists amongst the particles, which is the cause of their elasticity. Cohesion is illustrated by the following facts:—When portions of the same size are cut from two leaden bullets, and the fresh surfaces being brought into contact, and slightly pressed, they will unite, and appear as if they had been originally cast in one piece. Fresh-cut surfaces of India-rubber cohere in a similar manner. There is a species of attraction called *adhesive* attraction, instances of which come frequently under observation. If water be poured from a jug which has not a projecting lip, it will not fall perpendicularly, but run down the outside of the vessel. Hence the reason of having a spout to such utensils. A plate of glass, when brought into contact with a level surface of water, adheres to it with considerable tenacity, and resists a separation. Pieces of wood floating in a pond attract each other, and remain in contact, and the wrecks of vessels, when the sea is smooth, are often found gathered together in heaps.

There is a species of attraction called *capillary*, which takes place under the following circumstances:—when one end of an open glass tube is put into the water, the enclosed liquid stands above the level of that on the outside, and it rises always the higher the smaller the bore of the tube is; the surrounding glass, being thus nearer to the water, attracts it more powerfully. A piece of lump sugar, whose lowest corner touches the water, soon becomes moistened throughout. Thus also the wick of a lamp or candle draws up the oil or tallow to supply combustion. The sap which rises from the roots to the tops of vegetables, though chiefly an action of vegetable life, partly depends on capillary attraction for its ascent.

We come now to a most important and interesting part of the subject—*chemical attraction or infinity.*—(See also article "Chemistry" in another part of this work.)

There are in nature about fifty-four substances which are termed elements, from the impossibility of human skill or industry to reduce them to anything simpler. These elements, uniting together by the power of chemical attraction, form the infinite variety of objects around us. The investigation of this subject, from its great extent and importance, prevents us from doing more in this place than giving a general idea of it, sufficiently attractive to induce the reader the reader to feel interested in the science of chemistry, which will well repay a lengthened study of that important branch of scientific knowledge.

Chemical Attraction is exercised between particles of dissimilar bodies, which, uniting, form a new substance, possessing properties different from those of its ingredients. Frequently, indeed, the qualities of the compound are exactly the opposite of its constituents, as in the case of water. This liquid is composed of hydrogen, one of the most inflammable bodies known, and oxygen, the grand supporter of combustion on the globe. Yet, when these are united, they form a fluid possessing qualities so totally different from their own, that it destroys all flame whatsoever, unless, indeed, the heat be so intense as to decompose the water; and frequently the same component parts, when united in different proportions, produce the most opposite substances. Thus, the common air that we breathe is composed of the very same elements as aquafortis. All bodies have not a chemical attraction for each other. Thus, oil and water, though shaken together, will not unite; but if lime-water is employed, a union takes place, and the result is a new compound, which is insoluble in water. Again—sulphuric acid, or vitriol, will not dissolve or unite with gold; but it will with copper or iron, (besides a great variety of other bodies,) forming in the first instance sulphate of copper, or blue vitriol; and in the second, sulphate of iron, or copperas. Common sea-sand and soda, when heated, attract each other, and, combining, form glass. What are called acids and alkalies have a strong affinity for each other, and their compounds form a class of substances called salts, which are most important in the arts and manufactures. Oil of vitriol, and soda, for instance, combine with great facility, and the compound is Glauber salts.

Thus, by the existence and exercise of this peculiar property of matter, are formed the endless diversity of substances which constitute the mass of our globe. It is impossible to contemplate the subject of attraction, in general, without a feeling of religious reverence and awe for the Divine Being who drew the mighty plan—set it in motion at first, and still upholds it.—But the wisdom of it is not more conspicuous than the benevolence. Indeed, the operations of all the various laws of nature are to man so many great sources of enjoyment. He stands, as it were, the centre of the system of life and nature around him.—What attraction is in the abstract, human sagacity has not yet, and probably never will unravel. The chain of cause and effect here breaks off, or rather for the present may be said to terminate, in the Deity.

Philosophers may, however, discover a proximate cause, and even trace the golden links through a thousand beautiful windings, but in a Divine Creator they must verge at last.

ASTRONOMY.

THE MOTION OF THE EARTH.

We shall commence this article by selecting that portion which most is interesting to us, the earth; and after endeavouring to form a distinct idea of the part which it performs in the general system, proceed from thence to form some conception of the grandeur and immensity of the universe. Let us suppose the earth at its creation to have been projected forwards into universal space. We know that if no obstacle impeded its course, it would proceed in the same direction, and with a uniform velocity for ever; but the attraction of the sun stopped its onward progress, and confines it to a centre. It then commenced a course which it has pursued ever since it first issued from the hand of its Creator, and which there is every reason to suppose it will follow as long as it remains in existence. The earth travels round the sun, not in a circle, but an ellipsis, of which the sun occupies one of the *foci;* and in its course the earth alternately approaches and recedes from it; so that what at first appears to be a dangerous irregularity, is the means by which the most perfect order and harmony are produced. The earth then travels on at a very unequal rate, its velocity being accelerated as it approaches the sun, and retarded as it recedes from it.

The part of the earth's orbit nearest the sun is called its *perihelion*, that part most distant from the sun its *aphelion;* and the earth is about three millions of miles nearer the sun at its perihelion than at its aphelion. The reader will be surprised to learn that, during the height of our summer, the earth is in that part of its orbit which is most distant from the sun, and it is during the severity of winter that it approaches nearest to it. The difference, hovever, of the earth's distance from the sun in summer and winter, when compared with its total distance from the sun, is but inconsiderable, for three millions of miles sinks into insignificance when compared with ninety-five millions, which is our mean distance from the sun. The change of temperature arising from this difference, would in itself scarcely be sensible, and it is completely overpowered by other causes which produce the variations of the seasons; but the explanation of these must be deferred till we have made some further observations on the heavenly bodies. Since the earth moves with the greatest velocity in that part of its orbit nearest the sun, it must complete its journey through one-half of its orbit in a shorter time than through the other half; and, in fact, it is about seven days longer in performing our summer half of its orbit than the winter half. The planets are celestial bodies which revolve round the sun, on the same principle, and they are supposed to resemble the earth also in many other respects; and we are led by analogy to consider them as inhabited worlds.

Some of the planets are proved to be larger than the earth; it is only their immense distance from us which renders their apparent dimensions so small. Now, if we consider them as enormous globes, instead of small twinkling spots, we shall find it most consistent with our ideas of the Divine wisdom and beneficence, to suppose that these celestial bodies should be created for the habitation of beings who are, like us, blessed by his Providence. Hence, in a moral, as well as a physical point of view, it is most rational to consider the planets as worlds revolving round the sun; and the fixed stars as other suns, each of them probably attended by its system of planets, to which they respectively impart their influence. Our telescopes are brought to such a degree of perfection, that from the appearances which the moon exhibits when seen through them, we have probable reason to conclude that it is a habitable globe; its mountains and valleys are very perceptible, and some astronomers have even imagined that they saw volcanoes in it.

The planets which are supposed to revolve round the fixed stars must of course be much smaller than the suns which give them light; and the distance which makes these suns appear to us like stars must render their planets invisible; besides, the light of these planets would be much more feeble than that of the fixed stars; there would be exactly the same sort of difference as between the light of the sun and that of the moon, the first being a fixed star, the second a planet.

According to the laws of attraction, the planets belonging to our system, all gravitate towards the sun; and this force, combined with that of projection, occasion their revolution round the sun, in orbits more or less elliptical, according to the proportion which these two forces bear to each other. But the planets have also another motion: they revolve upon their axis. The axis of a planet is an imaginary line which passes through its centre, which produces day and night. With that side facing the sun, it is day; and with the opposite side which remains in darkness, it is night. Our earth, which we consider as a planet, is twenty-four hours in performing one revolution on its axis; in that period of time therefore we have a day and a night. Hence this revolution is called the earth's diurnal or daily motion; and it is this revolution of the earth from west to east which produces an apparent motion of the sun, moon, and stars in the contrary direction.

THE PLANETS.

The planets are distinguished into primary and secondary. Those which revolve immediately about the sun are called primary. Many of these are attended in their course by smaller planets, which revolve round them; these are called secondary planets, satellites or moons. Such is our moon, which accompanies the earth, and is carried with it round the sun. The sun is the general centre of attraction to our system of planets; but the satellites revolve round the primary planets, on account of their great proximity. The force of attraction is not only proportional to the quantity of matter, but to the degree of proximity of the attracting body. This power being weakened by diffusion, diminishes as the squares of the distance increase. The square is the product of a number multiplied by itself; so that a planet situated at twice the distance at which we are from the sun would gravitate four times less than we do, the product of two multiplied by itself being four. The more distant planets, therefore, move slower in their orbits; for their projectible force must be proportioned to that of attraction. This diminution of attraction by the increase of distance also accounts for the motion of the secondary round the primary planets, in preference to the sun; for the vicinity of the primary planets renders their attraction stronger than that of the sun. But since the attraction between bodies is mutual, the primary planets are also attracted by their satellites. The moon attracts the earth, as well as the earth the moon, but as the latter is the smaller body, her attraction is proportionally less. The result is, that neither the earth revolves round the moon, nor the moon round the earth: but they both revolve round a point which is their common centre of gravity, and which is as much nearer the earth than the moon, as the weight of the former exceeds that of the latter. If two bodies are fastened together by a wire or bar, their common centre of gravity will be in the middle of the bar, provided the bodies are of equal weight; and if they differ in weight, then it will be nearer the larger body. Attraction is the tie which unites the earth and moon; and if these bodies had no projectile force which prevented their mutual attraction from bringing them together, they would meet at their common centre of gravity.

The earth, then, has three different motions; it revolves round the sun, upon its axis, and around the point towards which the moon attracts it; and this is the case with every planet which is attracted by satellites. The complicated effect of this variety of motions produces irregularities, which, however, it is not necessary to mention at present. The planets act on the sun in the same manner as they are themselves acted on by their satellites; but the gravity of the planets (even when taken collectively,) is so trifling compared with that of the sun, that they do not cause the latter to move so much as one half of its diameter. The planets do not, therefore, revolve round the centre of the sun, but round a point, at a small distance from the centre, about which the sun also revolves. The sun also revolves on its axis. This motion is ascertained by observing certain spots which disappear and re-appear regularly at stated times.

The great distance of the planets render their motion apparently so slow, that the eye is not sensible of their progress in their orbit, unless we watch them for some considerable length of time; in different seasons they appear in different parts of the heavens. The sun is the common centre of the whole.

Mercury is the planet nearest the sun; his orbit is consequently contained within ours; but his vicinity to the sun occasions his being nearly lost in the brilliancy of his rays; and when we see this planet, the sun is so dazzling that very accurate observations cannot be made upon him. He performs his revolution round the sun in about eighty-seven days, which is consequently the length of his year; the time of his rotation on his axis is not accurately known; his distance from the sun is computed to be thirty-seven millions of miles, and his diameter three thousand two hundred and twenty-four miles. The heat of this planet is so great, that water cannot exist there but in a state of vapour, and metals would be liquified.

Venus, the next in the order ot planets, is sixty-eight millions of miles from the sun; she revolves about her axis in twenty-three hours and twenty-one minutes, and goes round the sun in two hundred and twenty-four days seventeen hours. The diameter of Venus is seven thousand six hundred and eighty-seven miles. The orbit of Venus is within ours; during nearly one half of her course in it we see her before sunrise, and she is called the morning star; in the corresponding part of her orbit, on the other side, she rises later than the sun. We then cannot see her rising, as she rises in the day time; but she also sets later, so that we perceive her approaching the horizon after sunset; she is then called Hesperus, or the evening star.

The planet next to Venus, is the Earth, of which shall soon speak at length; at present we shall only observe, that we are ninety-five millions of miles distant from the sun—that we perform our annual revolution in three hundred and sixty-five days five hours and forty-nine minutes—and are attended in our course by a single moon.

Then follows Mars. He can never come between us and the sun like Mercury and Venus; his motion, however, is very perceptible, as he may be traced to different situations in the heavens; his distance from the sun is one hundred and forty-four millions of miles; he turns on his axis in twenty-four hours and thirty-nine minutes, and he performs his annual revolution in about six hundred and eighty-seven of our days; his diameter is four thousand one hundred and eighty-nine miles. Then follow four very small planets—Juno, Ceres, Pallas, and Vesta, which have been recently discovered, but whose dimensions and distances from the sun have not as yet been very accurately ascertained.

Jupiter is next in order. This is the largest of all the planets; he is about four hundred and ninety millions of miles distant from the sun, and completes his annual period in nearly twelve of our years; he revolves upon his axis in about ten hours; he is about one thousand four hundred times as large as our earth, his diameter being eighty-nine thousand one hundred and seventy miles. He is attended by four moons.

The next planet is Saturn, whose distance from the sun is about nine hundred million of miles. His diurnal rotation is performed in about ten hours and a quarter; his annual revolution is nearly thirty of our years; his diameter is seventy-nine thousand miles. This planet is surrounded by a luminous ring, the nature of which astronomers are much at a loss to conjecture. He has seven moons.

Lastly, we observe the Georgium Sidus, discovered by Dr. Herschel, and which is attended by six moons. His numerous moons are, however, far from making so splendid an appearance as ours; for they can only reflect the light which they receive from the sun; and both light and heat decrease in the same ratio or proportion to the distances as gravity; consequently, Saturn, which is nearly ten times the distance at which we are from the sun, has a hundred times less heat and light. To us such a climate would not be habitable; but this furnishes no argument against the supposition that these planets are worlds, peopled with beings whose bodies are adapted to the various temperatures and elements in which they are situated. Whether we judge from the analogy of our own earth, or from that of the great and universal beneficence of Providence, we may readily conjecture this to be the case: and an inhabitant of Mercury might with as much plausibility pity us for the intense coldness of our situation, or those of Jupiter and Saturn for our intolerable heat, as we can draw any inferences against their existence, from the circumstance that we, constituted as we are, could not live there.

Comets are supposed to be planets. The re-appearance of some of them prove that they revolve round the sun; but in orbits so extremely eccentric, and running to such a distance from the sun, that they disappear for a great number of years. If they are inhabited it must be by a species of beings very different, not only from the inhabitants of this, but from that of any other of the planets; as they must experience the greatest vicissitudes of heat and cold; their heat at that part of their orbit nearest to the sun is computed to be greater than red hot iron. In this part of its orbit the comet emits a luminous vapour, called the tail, which it gradually loses as it recedes from the sun; and the comet itself totally disappears from our sight in the more distant parts of its orbit, which, in most cases, extends considerably beyond that of the farthest planet. The number of comets belonging to our system cannot be ascertained, as some of them are several centuries before they make their re-appearance. The number that are known by their regular re-appearance is very small.

The ancients, in order to recognise the fixed stars, formed them into groups, to which they gave the name of the figures delineated on the celestial globes. In order to show their proper situations in the heavens, they should be painted on the internal surface of a hollow sphere, from the centre of which they should be viewed; they would then be seen as they appear in the heavens. The twelve constellations, called the Signs of the Zodiac, are those which are so situated, that the earth in its annual revolution passes directly between them and the sun. Their names are, Aries, the Ram; Taurus, the Bull; Gemini, the twins; Cancer, the Crab; Leo, the Lion; Virgo, the Virgin; Libra, the Balance; Scorpio, the Scorpion; Sagittarius, the Archer; Capricornus, the Wild Goat; Aquarius, the Water carrier; Pisces, the Fishes; the whole occupying a complete circle, or broad belt, in the heavens, called the Zodiac. Hence, a line drawn from the earth, and passing through the sun, is said to be in that constellation at which the line terminates.

The perfection of astronomical instruments has afforded the prospect of being able to determine the annual Parallax, and consequently the distance of the fixed stars; but the quantity of deviation is so small as to have hitherto eluded the closest observation. It cannot amount to a single second in the most conspicuous, and probably the nearest of the stars. These luminous bodies must therefore be more distant at two hundred thousand times than the measure of the diameter of the earth. The light emitted from such neighbouring suns, though it flies with incredible rapidity, must yet travel more than six thousand years before it reaches the confines of our system. But scattered over the immensity of space, there may exist bodies which, by their magnitude and predominant attraction, retain or recal the rays of light, and are lost in solitude and darkness. Had the celerity of the luminous particles not exceded four hundred miles in a second, we should never have enjoyed the cheering beams of the sun. They would have been arrested in their journey, and drawn back to their source before they reached the orbit of Mercury. But a star similar to our sun, and having a diameter sixty-three times greater, would entirely overpower the impetus of light.

Whether the apparent difference of size and brilliancy of the stars proceed from their various degrees of remoteness, or of dimension, is a point which astronomers are unable to ascertain. Considering them as suns, we know no reason why they should not vary in size, as well as the planets belonging to them.

It may, perhaps, be objected to this system of the universe, that it is directly in opposition to the evidence of our senses, to which it is plain and obvious that the earth is motionless, and that the sun and stars revolve round it. But our senses, or at least the inferences we draw from them, too often mislead us, for us to place implicit reliance on them. When sailing on the water with a very steady breeze, the houses, trees, and every object appear to move, whilst we are insensible of the motion of the vessel in which we sail. It is only when some obstacle impedes our motion, that we are conscious of moving; and were you to close your eyes while sailing on calm water, with a steady wind, you would not perceive that you moved, for you could not feel it, and you could only see it by observing the change of place of the objects on shore. So it is with the motion of the earth: everything on its surface, and the air that surrounds it, accompanies it in its revolution—it meets with no resistance, therefore we are insensible of motion.

The apparent motion of the sun and stars affords us the same proof of the earth's motion, that the crew of a vessel has of their motion from the apparent motion of the objects on shore. Imagine the earth to be sailing round its axis, and successively passing by every star, which, like the objects on land, we suppose to be moving, instead of ourselves. In balloons, the earth appears to sink beneath the balloon, instead of the balloon rising above the earth.

It is a law which we discover throughout Nature, and worthy of its great Author, that all its purposes are accomplished by the most simple means. We have no reason to suppose this law infringed in order that our earth may remain at rest, while the sun and stars move round us: their regular motions, which are explained by the laws of attraction, on the first supposition, would be unintelligible on the last, and the order and harmony of the universe be destroyed. What an immense circuit the sun and stars would make daily, were their apparent motions real! We know many of them to be bodies more considerable than our earth; for our eyes vainly endeavour to persuade us, that they are little brilliants sparkling in the heavens, while science teaches us that they are immense spheres, whose apparent dimensions are diminished by distance. If the heavenly bodies revolved round our earth in twenty-four hours, the centrifugal force implied in so rapid a motion would be quite destructive; and no power can be assigned which would be sufficient to balance it; grindstones, driven by machinery, in manfactories, have been known to fly in pieces from their great velocity. Why then should these enormous globes traverse such an immensity of space, merely to prevent the necessity of our earth revolving on its axis? The motion produced by the revolution of the earth on its axis is about thirteen miles and a half in a minute, to an inhabitant of London. A person at the equator moves much quicker; and one situated near the poles much slower, since they each perform a revolution in twenty-four hours. But in performing its revolution round the sun, every part of the earth moves with an equal velocity, and this velocity is no less than a thousand miles in a minute.

In ancient times, the earth was supposed to occupy the centre of the system; and the sun, moon, and stars to revolve around it. This was the system of Ptolemy; but so long ago as the beginning of the sixteenth century it was discarded, and the solar system such as we have shown was established by the celebrated astronomer Copernicus and his followers, and is hence called the Copernican system. But the the theory of gravitation, the source whence this beautiful and harmonious arrangement flows, we owe to the powerful genius of Sir Isaac Newton, who lived at a much later period.

It is far less difficult to trace by observation the motion of the planets, than to divine by what power they are impelled and guided. The idea of gravitation, it is said, was first suggested to Sir Isaac Newton, by a circumstance from which one should little have expected so grand a theory to have arisen. During the prevalence of the plague in the year 1665, Newton retired into the country to avoid the contagion. When sitting one day in his orchard, he observed an apple fall from a tree, which led to a train of thought whence his grand theory of gravitation was ultimately developed. His first reflection was whether the apple would fall to the earth, if removed to a great distance from it; then, how far it would cease to be attracted; would it retain its tendency to fall at the distance of a thousand miles, or ten thousand, or to the distance of the moon? And here the idea occurred to him, that it was not impossible the moon herself might have a similar tendency, and gravitate to the earth in the same manner as the bodies on or near its surface, and this gravity might possibly be in the power which balanced the centrifugal force implied in her power in her orbit. It was natural, then, to extend this idea to the other planets, and consider them as gravitating towards the sun, in the same manner as the moon gravitates towards the earth. He followed up this beautiful hypothesis, by a series of calculations and demonstrations unparalleled for their originality, and the industry and judgment with which they were conducted, until he established the stupendous doctrine of universal gravitation! Who would imagine that the simple circumstance of the fall of an apple would have led to such magnificent results? It is the mark of superior genius to find matter for observation and research in circumstances which, to the ordinary mind, appear trivial, because they are common, and with which they are satisfied because they are natural, without reflecting that Nature is our grand field of observation—that within it is contained our whole store of knowledge: in a word, that to study the works of Nature, is to learn to appreciate and admire the wisdom of God. Thus it was the simple circumstance of the fall of an apple which led to the distovery of the laws upon which the Copernican system is founded; and whatever credit this system had obtained before, it now rests upon a basis from which it cannot be shaken.

THE EARTH.

In explaining the effects resulting from the earth's annual and diurnal motion, it is necessary that the reader should understand the terrestrial globe. This globe represents the earth. The line which passes through its centre, and on which it turns is the axis; and the two extremities of the axis are the poles, distinguishad by the names of the north and south poles. The circle which divides the globe into two equal parts between the poles is called the equator or equinoctial line; that part of the globe to the north of the equator is the northern hemisphere; that part to the south of the equator, the southern hemisphere. The small circle, which surrounds the north pole, the antarctic circle. There are two immediate circles between, the polar circles and the equator,—that to the north, called the tropic of Cancer; that to the south, called the tropic of Capricorn. Lastly, this circle which divides the globe into two equal parts, crossing the equator, and extending northward as far as the tropic of Cancer, and southwards as far as the tropic of Capricorn, is called the ecliptic.

The spaces, between the several parallel circles on the terrestrial globe, are called zones; that which is comprehended between the tropics is distinguished by the name of the torrid zone; the spaces which extend from the tropics to the polar circles, the north and south temperate zones; and the space contained within the polar circles the frigid zones.

The several lines which are drawn from one pole to the other, cutting the equator at right angles, are called meridians. When any one of these meridians is exactly opposite the sun, it is mid-day, or twelve o'clock in the day, with all the places situated on that meridian; and with the places situated on the opposite meridian, it is consequently midnight. To places situated equally distant from these two meridians, it is six o'clock. If they are to the east of the sun's meridian, it is six o'clock in the afternoon, because the sun will have previously passed over them; if to the west, it is six o'clock in the morning, and the sun will be proceeding towards that meridian.

Those circles which divide the globe into two equal parts, such as the equator and the ecliptic, are called great circles—to distinguish them from those which divide it into two unequal parts, as the tropics and polar circles, which are called small circles. All circles are divided into three hundred and sixty equal parts called degrees; and these degrees into sixty equal parts called minutes.

Besides the usual division of circles into degrees, the ecliptic is divided into twelve equal parts, called signs, which bear the name of the constellations through which this circles passes in the heavens. The degrees measured on the meridians from north to south, or south to north, are called degrees of latitude; those measured from east to west on the equator, or any of the lesser circles parallel to it, are called degrees of longitude; these circles are called parallels of latitude, because being everywhere at the same distance from the equator, the latitude of every point contained in any one of them is the same.

The degrees of longitude must necessarily vary in length according to the dimensions of the circle on on which they are reckoned; those, for instance, at the polar circles, will be considerably smaller than those at the equator. The degrees of latitude, on the contrary, never vary in length, the meridians on which they are reckoned being all of the same dimensions. The length of a degree of latitude is sixty geographical miles, which is equal to sixty nine and a half English statute miles. The degrees of longitude at the equator would be of the same dimensions were the earth a perfect sphere, but its form is not exactly spherical, being somewhat protuberant about the equator, and flattened towards the poles. This form proceeds from the superior action of the centrifugal power at the equator. The revolution of the earth on its axis gives every particle a tendency to fly off from the centre. This tendency is stronger or weaker in proportion to the velocity with which the particle moves. Now a particle situated near one of the polar circles, makes one rotation in the same space of time as a particle at the equator; the latter therefore having a much larger circle to describe, travels proportionally faster, consequently the centrifugal force is much stronger at the equator than at the polar circles: it gradually decreases as you leave the equator and approach the poles, where, as there is no rotatory motion, it entirely ceases. Supposing therefore, the earth to have been originally in a fluid state, the particles in the torrid zone would recede much farther from the centre than those in the frigid zone; the polar regions would become flattened, and those about the equator elevated. According to the same rule, our heads move with greater velocity than our feet; and on the summit of a mountain, our velocity is greater than in a valley; for the head is more distant from the centre of motion than the feet—the mountain top than the valley. Even at the equator, however, the force of gravity preponderates very considerably, being at the equator two hundred and eighty eight times greater than the centrifugal force.

It would be natural to suppose that the prominence at the equator and depression at the poles would render the attraction of gravity stronger at the former; so that a body would weigh heavier at the equator than at the poles. This, however, is erroneous. The manner in which the force of gravity varies, at different spots on the surface of the earth, depends on considerations too complicated to be here explained; but the general result is that, although the difference in different situations is very small, the nearer any part of the surface is to the centre of attraction, the more strongly it is attracted. We refer, however, only to any situation on the surface of the earth Were you to penetrate into the interior, the attraction of the parts above you would counteract that of the parts beneath you, and consequently diminish the power of gravity in proportion as you approached the centre; and if you reached the point, being equally attracted by the parts all around you, gravity would cease, and you would be without weight. Bodies therefore gravitate less, and consequently weigh less, at the equator than at the poles, while their centrifugal force is much greater; and as this force tends to drive bodies from the centre, it is necessarily opposed to, and must decrease tho power of gravity. There are then two causes which render bodies lighter in weight at the equator than at the poles—the diminution of gravitation, and the increase of the centrifugal force.

We shall now explain the variation of the Seasons, and the difference of the length of the days and nights in those seasons—both effects resulting from the same cause. In moving round the sun, the axis of the earth is not perpendicular to the plane of its orbit; in other words, its axis does not move round the sun in an upright position, but slanting or oblique. In the midst of summer, the globe is situated at what is called the summer solstice, which is on the 21st of June. The north pole is then inclined towards the sun, and the northern hemisphere enjoys much more of its rays than the southern. The sun now shines over the whole of the north frigid zone; and notwithstanding the earth's diurnal revolution, it will continue to shine upon it as long as it remains in this situation, whilst the south frigid zone is at the same time completely in obscurity.

Let the earth now set off from its position in the summer solstice, and carry it round the sun: observe that the axis must always be inclined in the same direction, and the north pole point to the same spot in the heavens. There is a fixed star situated near that spot—which is hence called the North Polar Star. The earth has now gone through one quarter of its orbit, and is arrived at that point at which the ecliptic crosses the equator, and which is called the autumnal equinox. The sun now shines from one pole to another, as it would constantly do were the axis of the earth perpendicular to its orbit, the inclination of the axis being now neither towards the sun nor in the contrary direction. At this period of the year the days and nights are equal in every part of the earth, excepting at the very poles; but the next step she takes in his orbit involves the north pole in darkness, while it illumines that of the south. This change was gradually preparing as the earth moved from summer to autumn; the arctic circle begins to have short nights, which increase as the earth approaches the autumnal equinox; and the instant it passes that point, the long night of the north pole commences, and the south pole begins to enjoy the light of the sun. As the earth proceeds in its orbit, the days shorten, and the nights lengthen, throughout the northern hemisphere, until it arrives at the winter solstice, on the 21st of December, when the north frigid zone is entirely in darkness, and the southern enjoys uninterrupted daylight. Exactly half of the equator, it will be observed, is enlightened in every position, and consequently the day is there always equal to the night.

The inhabitants of the torrid zone, it may be observed, have much more heat than we have, as the sun's rays fall perpendicularly upon them, while they shine obliquely on the temperate, and almost horizontally on the frigid zone; for during their long day the sun moves round at no great elevation above their horizon without either rising or setting; the only observable difference is, that it is more elevated by a few degrees at midday than at midnight; but at the poles themselves, the sun travels round in the course of twenty-four hours nearly at the same elevation from the horizon, rising every day a very little higher from the vernal equinox till midsummer, and declining after that period till the autumnal equinox, when their long night begins.

To a person placed in the temperate zone, as we are in England, the sun's rays will shine neither so obliquely as at the poles, nor so vertically as at the equator; but will fall upon him more obliquely in autumn and winter than in summer. Therefore, the inhabitants of the earth between the polar circles and the equator will not have merely one day and one night in the year, as happens at the poles; nor will they have equal days and equal nights, as at the equator; but their days and nights will vary in length at the different times of the year, according as their respective poles incline towards or from the sun, and the difference will be greater in proportion to their distance from the equator. During the other half of her orbit, the same effect takes place in the southern hemisphere, as what we have just remarked in the northern. When the earth arrives at the vernal equinox, where the ecliptic again cuts the equator, on the 22nd of March, she is situated with respect to the sun, exactly in the same position as in the autumnal equinox, excepting that it is now autumn in the southern hemisphere, whilst it is spring with us; for the half of the globe which is enlightened extends exactly from one pole to the other: the sun rises to the north pole and sets to the south pole. On the two days of the eqninox the sun is visible at both poles; but only half of it is seen from either, the other half being concealed by the horizon.

The sun is nearly three of our days in rising and setting at the poles. About thirty hours, or rather more, before he reaches the exact period of the autumnal equinox, the upper edge or limb of the sun begins to be visible at the south pole; and it is there seen constantly travelling round the horizon, and gradually rising higher and higher, till at the end of about sixty hours, after revolving nearly two and a half times round the horizon, the whole of its orb is visible.

At the same moment that the edge of the sun becomes visible at the south pole, the same edge which appears as the lower limb at the north pole, begins to dip below the horizon; but the sun still continues visible, travelling round the horizon, more and more of it being hid, till at the end of sixty hours, it totally disappears, just at the same moment when it is fully seen at the south pole. As the earth proceeds towards summer, the days lengthen in the northern hemisphere, and shorten in the southern, till the earth reaches our summer solstice, which brings it again to the spot whence we first accompanied him.

The mind can find no object of contemplation more sublime than the course of this magnificent globe, impelled by the combined powers of projection and attraction to roll in one invariable course around the source of light and heat; and what can be more delightful than the beneficent effects of this vivifying power on its attendant planet? It is at once the grand principle which animates and fecundates Nature.

The sun's rays afford less heat when in an oblique direction than when perpendicular, because few of them fall upon an equal portion of the earth. This accounts for the greater heat of summer, as the sun shines less obliquely in summer than in winter. But there is also another reason why oblique rays give less heat than those which are perpendicular; the former have a greater portion of the atmosphere to traverse; and though it is true that the atmosphere is itself a transparent body, it does not admit the passage of the sun's rays quite freely; and besides it is always loaded more or less with dense and foggy vapour, which the rays of the sun cannot easily penetrate; therefore the greater the quantity of atmosphere the sun's rays have to pass through in their way to the earth, the fewer of them will reach it.

The diminution of heat, morning and evening, is also owing to the greater obliquity of the sun's rays; and as such, they are affected by both the causes which have just been explained. The difficulty of passing through a foggy atmosphere is more particularly applicable to them, as mists and vapours are very prevalent about the time of sunrise and sunset. But the diminished obliquity of the sun's rays is not the sole cause of the heat of summer; the length of the days greatly conduces to it; for the longer the sun is above the horizon, the more heat he will communicate to the earth, and yet, though both the longest days, and the most perpendicular rays are on the 21st of June, the greatest heat prevails in July and August. To account for this, you must reflect, that those parts of the earth, which are once heated, retain the heat for a considerable length of time; and the additional quantity they receive occasions an elevation of temperature, although the days begin to shorten, and the sun's rays to fall more obliquely. For the same reason we have generally more heat at three o'clock in the afternoon than at twelve when the sun is in the meridian. As long as the sun continues to communicate more heat than the earth parts with in a given time, so long the heat of the earth will increase, even though the rate at which it receives new heat from the sun is diminished.

There is one more observation to make relative to the earth's motion, which is, that although we have but 365 days and nights in the year, she performs 366 complete revolutions on her axis during that time. This is owing to the progressive motion of the earth in its orbit, whilst it revolves on its axis: as it advances almost a degree westward in its orbit, in the same time that it completes a revolution eastward on its axis; it must revolve nearly one degree more, in order to bring the same meridian back to the sun. These small daily portions of rotation are each equal to the three hundred and sixty-fifth part of a circle, which at the end of the year amounts to one complete rotation. If the earth, then, had no other than its diurnal motion, we should have 366 days in the year; or rather we should have 366 days in the same period of time that we now have 365; for if we did not revolve round the sun, we should have no natural means of computing years.

In regard to time, we must add, that the earth's diurnal motion, on an inclined axis, together with its annual revolution in an elliptic orbit, occasions so much complication in its motion as to produce many irregularities: therefore true equal time cannot be measured by the sun. A clock which was always perfectly correct, would in some parts of the year be before the sun, and in other parts after it. There are but four periods in which the sun and a perfect clock would agree, which are, the 15th of April, the 16th of June, the 31st of August, and the 24th of December. The greatest difference between solar time and true time amounts to between fifteen and sixteen minutes. Tables of the equation of time are constructed for the purpose of pointing out and correcting these differences between solar and equal meantime, which is the denomination given by astronomers to true time.

THE MOON.

LET us now turn our attention to the moon. This satellite revolves round the earth in the space of twenty-seven days eight hours, in an orbit nearly coinciding with the plane of the earth's orbit, and accompanies us in our revolution round the sun. Her motion, therefore, is of a complicated nature; for as the earth advances in her orbit whilst the moon goes round her, the moon proceeds in a sort of progressive circle. There are also other circumstances which interfere with the simplicity and regularity of the moon's motion, but which are too intricate for us to notice in our limited space.

The moon always presents the same face to us, by which it is evident that she turns but once upon her axis while she performs a revolution round the earth; so that the inhabitants of the moon have but one day and one night in the course of a lunar month. Since we always see the same hemisphere of the moon, the inhabitants of that hemisphere alone can perceive the earth. One half of the moon, therefore, enjoys our light every night, while the other half has constantly nights of darkness; and we appear to the inhabitants of the moon under all the changes or phases which the moon exhibits to us.

When the moon is full, she is said to be in opposition—when a new moon, to be in conjunction with the sun. At each of these times, the sun, the moon, and the earth are in the same right line; but in the first case, the earth is between the sun and the moon; in the second, the moon is between the sun and the earth. An eclipse can take place only when the sun, moon, and earth are in a right line. When the moon passes between the sun and the earth, she intercepts his rays, or, in other words, casts a shadow on the earth; then the sun is eclipsed, and the daylight gives place to darkness, while the moon's shadow is passing over us. When, on the contrary, the earth is between the sun and the moon, it is we who intercept the sun's rays, and cast a shadow on the moon; she then disappears from our view, and is eclipsed.

Why then, it may be asked, have we not a solar and a lunar eclipse every month?

The planes of the orbits of the earth and the moon do not exactly coincide, but cross or intersect each other; and the moon generally passes on either one side or the other when she is in conjunction with, or in opposition to, the sun, and therefore does not intercept the sun's rays, or cause an eclipse; for this can take place only when the earth and moon are in conjunction near those parts of their orbits which cross each other (called the nodes of their orbits), because it is then only that they are both in the same plane, and in a right line with the sun. A partial eclipse takes place when the moon, in passing by the earth, does not entirely escape her shadow. When the eclipse happens precisely at the nodes, they are not only total, but last for some length of time.

When the sun is eclipsed, the total darkness is confined to one particular part of the earth, where the moon is above the horizon.

When the moon eclipses the sun to us, the earth is eclipsed to the moon; for if the moon intercepts the sun's rays, and casts a shadow on us, we must necessarily disappear to the moon, but only partially—a black spot will appear to pass over the earth.

In the distant planets, few days elapse without an eclipse taking place; for among the number of the satellites, one or other of them is continually passing into the shadow of the planet, or between the planet and the sun. Astronomers are so well acquainted with the motion of the planets and their satellites, that they have calculated not only the eclipses of our moon, but those of Jupiter, with such perfect accuracy, that it has afforded a means of ascertaining the longitude. When, as on land, we know where we are situated, there is no difficulty in ascertaining the latitude or longitude of the place, by referring to a map; but the question is, to find out our situation when we do not know where we are; for instance, at sea, interrupted in our course by storms, a map would afford no assistance in discovering where we were. The latitude may be found by taking the latitude of the pole: that is to say, observing the number of degrees that it is elevated above the horizon, for the pole appears more elevated as we approach it, and less as we recede from it. It is true that the pole is not visible to us; but the north pole points constantly to one particular part of the heavens, near which a star is situated, called the Polar Star. The altitude of the polar star is therefore nearly the same number of degrees as that of the pole; and this star is visible in clear nights from every part of the northern hemisphere, it furnishes an easy mode of ascertaining the latitude in all that half of the world. The latitude may be more accurately determined by other observations, which may be made on the sun, or any of the fixed stars; the situation, therefore, of a vessel at sea, with regard to north and south, is easily ascertained. The difficulty is respecting east and west—that is to say, its longitude. As there are no eastern poles from which we can reckon our distance, some particular spot must be fixed upon for that purpose. The English reckon from the meridian of Greenwich, where the Royal Observatory is situated; in French maps, the longitude is reckoned from Paris.

The rotation of the earth on its axis in twenty-four hours, from west to east, occasions, as we have already seen, an apparent motion of the sun and stars in the contrary direction, and the sun appears to go round the earth in the space of twenty-four hours, passing over fifteen degrees, or a twenty-fourth part of the earth's circumference every hour; therefore, when it is twelve o'clock in London, it is one o'clock in any place situated fifteen degrees to the east of London, as the sun must have passed the meridian of that place an hour before he reaches that of London. For the same reason, it is eleven o'clock in any place situated fifteen degrees to the west of London, as the sun will not come to that meridian till an hour later. If, then, the captain of a vessel at sea could know precisely what was the hour at London, by looking at his watch, and comparing it with the hour of the spot in which he was, he could ascertain the longitude. For this purpose he must be furnished with two watches—the one daily regulated by the sun, and the other unaltered. The former would indicate the hour of the place in which he was situated, and the latter the hour of London; and by comparing them together, he would be able to calculate his longitude; but the best watches are liable to imperfections, and should the time-keeper go too slow, there would be no means of ascertaining the error: implicit reliance, therefore, cannot be placed upon them.

Recourse is had, therefore, to the eclipses of Jupiter's satellites. A table is made of the precise time at which the several moons are eclipsed to a spectator at London. When they appear eclipsed to a spectator in any other spot, he may, by consulting the table, know what is the hour at London; for the eclipse is visible at the moment from whatever place on the earth it is seen. He has then only to look at the watch which points out the hour of the place in which he is, and by observing the difference of time there and at London, he may immediately determine his longitude.

Let us suppose that a certain moon of Jupiter is always eclipsed at six o'clock in the evening at London, and that a man at sea consults his watch, and finds that it is ten o'clock at night, where he is situated, at the moment the eclipse takes place; he would be sixty degrees east of London; for the sun which (apparently) travels fifteen degrees an hour, must have passed his meridian four hours before it reaches that of London; for this reason the hour is always later in London when the place is east longitude, and earlier when it is west longitude. Thus the longitude can be ascertained whenever the eclipses of Jupiter's moons are visible.

The longitude shows on what meridian you are situated, and the latitude on what part of that meridian; therefore, when you can ascertain both these, you discover the very spot in which you are situated. But it is not only the secondary planets which produce eclipses, for the primary planets near the sun eclipse him to those at a greater distance, when they come in conjunction in the nodes of their orbits; but as the primary planets are much longer in performing their course round the sun, than the satellites in going round their primary planets, these eclipses very seldom occur.

Mercury and Venus have, however, passed in a right line between the earth and the sun, but being at so great a distance, their shadows did not extend so far as the earth. No darkness was therefore produced on any part of our globe; but the planet appeared like a small black spot passing across the sun's disc: this is called a transit of the planet. It was by the transit of Venus that astronomers were enabled to calculate, with some degree of accuracy, the distance of the earth from the sun, and the dimensions of the latter.

The tides are produced by the attraction of the moon. The cohesion of fluids being much less than that of solid bodies, they more easily yield to the power of gravity; in consequence of which the waters immediately below the moon are drawn up in a protuberance, producing a full tide, or what is commonly called high-water, at the spot where it happens. According to this theory, it would be imagined that we should have the full tide only once in twenty-four hours—that is, every time that they were below the moon—while we find that we have two tides in the course of the twenty-four hours, and that it is high water with us and with our antipodes at the same time.

The influence of the sun on the tides is less than that of the moon; for observe, that the tides rise in consequence of the moon attracting one part of the waters more forcibly than another part: it is this inequality of attraction which produces full and ebb tides. Now the distance of the sun is so great, that the whole globe of the earth is comparatively but as a point, and the difference of attraction for that part of the waters most under its influence, and that part least subject to it, is but trifling; no part of the waters will be much elevated above, or much depressed below, their general surface, by its action. The sun has, however, a considerable effect on the tides, and increases or diminishes them as it acts in conjunction with, or in opposition to, the moon.

The moon is a month in going round the earth: twice during that time, therefore, at full and at change, she is in the same direction as the sun. Both these act in conjunction, on the earth, and produce very great tides, called spring-tides; but when the moon is in the intermediate parts of her orbit, the sun, instead of affording assistance, weakens her powers by acting in opposition to it; and smaller tides are produced, called neap-tides.

Since attraction is mutual between the moon and the earth, we produce tides in the moon; and these are more considerably in proportion as our planet is larger. Neither the moon nor the earth in reality assumes an oval form, for the land which intersects the water destroys the regularity of the effect. The orbit of the moon being nearly parallel to that of the earth, she is never vertical but to the inhabitants of the torrid zone; in that climate, therefore, the tides are greatest, and they diminish as you recede from it, and approach the poles; but in no part of the globe is the moon immediately above the spot where it is high-tide. All matter, by its inertion, offers some resistance to a change of state; the waters, therefore, do not readily yield to the attraction of the moon, and the effect of her influence is not complete until some time after she has passed the meridian.

The earth revolves on its axis in about twenty-four hours: if the moon were stationary, therefore, the same part of the globe would every twenty-four hours return beneath the moon; but as during our daily revolution the moon advances in her orbit the earth must make more than a complete rotation, in order to bring the same meridian opposite the moon: we are three-quarters of an hour in overtaking her. The tides, therefore, are retarded, for the same reason that the moon rises later, by three-quarters of an hour, every day. This, is only the average amount of the retardation. The time of the highest tide is modified by the sun's attraction, and is between those of the tides which would be produced by the separate action of the two luminaries. The action of the sun, therefore, makes the interval different on different days, but leaves the averagement unaffected.

MECHANICS.

ON THE LAWS OF MOTION, AND THE CENTRE OF GRAVITY.

THE science of Mechanics is founded on the laws of motion; it will therefore be necessary to explain these laws before we examine the mechanical powers. Motion consists in a change of place. A body is in motion whenever it is changing its situation with regard to a fixed point. Now, as one of the general properties of bodies is inertia, that is, an entire passiveness either with regard to motion or rest, it follows that a body cannot move without being put into motion: the power which put a body into motion is called *force;* thus the stroke of the hammer is the force which drives the nail; the pulling of the horse that which draws the carriage. Gravitation is the force which occasions the fall of bodies; cohesion that which binds the particles of bodies together; and heat, a force which drives them asunder. The motion of a body acted upon by a single force is always in a straight line, in the direction of which it received the impulse.

The rate at which the body moves, or the length of time which it takes to move from one place to another, is called its velocity; and it is one of the laws of motion that the velocity of the moving body is proportional to the force by which it is put in motion. The velocity of a body is called *absolute*, if we consider the motion of the body in space, without any reference to that of other bodies. When, for instance, a horse goes fifty miles in ten hours, his velocity is five miles an hour. It is termed *relative*, when compared with that of another body which is still in motion. Thus a man sailing in a ship may remain at rest relatively to the vessel, though he partakes of its absolute motion; but if he walk the deck in the same direction as that in which the ship is sailing, his absolute motion will be increased by the rate at which he moves along, and his relative motion will be the difference between his own absolute motion and that of the ship. So if two carriages go along the same road in the same direction, their relative velocity will be the difference of their absolute velocities; if in opposite directions, the same. If they start from the same point, along two roads, making an angle with each other, their relative motion will be measured by their distance, in a straight line, from each of the other after a given time, and the direction of that line. The absolute velocity of a body is measured by the space over which it moves, in some particular time, selected as the standard; the velocity per hour, for instance, would be shown by dividing the number of miles travelled over by the number of hours occupied in the journey. Thus—if you travel one hundred miles in twenty hours, and wish to know what is your velocity, you divide one hundred by twenty, and the answer will be five miles an hour. We say, also, that space is equal to the velocity multiplied by the time; if your velocity be three miles an hour, and you travel six hours, you will have gone in all a space of eighteen miles.

Uniform motion is that of a body which passes over equal spaces in equal times. It is produced by a force having acted on a body once, and having ceased to act, such as the stroke of a bat on a cricket-ball. But it may be said that the motion of a cricket-ball is not uniform, its velocity gradually diminishing till it falls to the ground. In answer to this objection, you must observe that the ball is inert, having no more power to stop than to put itself in motion; if it fall, therefore, it must be stopped by some force superior to that by which it was projected; and this force is gravity, which counteracts, and finally overcomes that of projection. If neither gravity nor any other force (such as the resistance of the air or friction of the ground) opposed its motion, the cricket-ball, or even a stone thrown by the hand, would proceed onwards in a right line and with a uniform velocity for ever! Yet we have no example of perpetual motion on the surface of the earth; because the causes referred to ultimately destroy all motion, whether produced by natural or artificial means.

When we study the celestial bodies, we find that Nature abounds with examples of perpetual motion, and that it conduces as much to the harmony of the system of the universe, as the prevalence of it would be to the destruction of all stability on the surface of the globe. Providence has therefore ordained insurmountable obstacles to perpetual motion here below; and though these obstacles often compel us to contend with great difficulties, yet the general result is, that order, regularity, and repose, so essential to the preservation of the various beings of which this world is composed.

Retarded motion is produced by some force acting on a body in a direction opposed to that which first put it in motion, and this gradually diminishes its velocity.

Accelerated motion is produced when the force which put a body in motion continues to act upon it during its motion, so that its velocity is continually increased. Let us suppose, that the instant a stone is let fall from a high tower, the force of gravity were annihilated: the stone would nevertheless descend; for a body having once received an impulse, will not stop (unless some obstacle impede its course), but move on with a uniform velocity. If, then, the force of gravity be not destroyed after having given the first impulse to the stone, but continues to act on it during the whole of its descent, it is easy to understand that its motion will be thereby accelerated. Let us suppose that the impulse given by the gravity to the stone during the first instant be equal to one; the next instant we shall find that an additional impulse gives the stone an additional velocity equal to one; so that the accumulated velocity is now equal to two; the following instant another impulse increases the velocity to three, and so on till the stone reaches the ground. The spaces described in a given time follow a law slightly different; for it has been ascertained both by experiment and calculations, that heavy bodies descending from a height by the force of gravity, fall sixteen feet in the first second of time, three times that distance in the next, five times in the third second, seven times in the fourth, and so on, regularly increasing both their velocities and the spaces described according to the number of seconds during which the body has been falling. Thus the height of a building, or the depth of a well, may be measured by observing the length of time which a stone takes in falling from the top to the bottom.

If a stone be thrown perpendicularly upwards, it is the same length of time ascending that it is descending. In the first case the velocity is diminished by the force of gravity; in descending it is accelerated by it. The force of projection given to a body in moving it upwards is equal to the force with which it strikes the ground when it descends again; and this latter force is the effect produced by gravity during the time of its fall. If a stone be thrown upwards gently, it will not rise high, and gravity will soon make it descend; if thrown with violence, it will rise higher, and gravity will be longer in bringing it back to the ground. Suppose that it be thrown with a force which will make it rise only sixteen feet, in that case it will fall in one second of time. Now it is proved, by experiment, that an impulse requisite to project a body sixteen feet upwards, will make it ascend that height in one second; here, then, the times of the ascent and descent are equal. But suppose it to be required to throw a stone twice that height, the force must be greater. Then the impulse of projection in throwing a body upwards, is equal to the accumulated effect produced by gravity during its descent; and it is the greater or less distance to which the body rises, that makes these balance each other, for it gives more time for the force of gravitation to act.

The *Momentum* of bodies is the force of power with which a body in motion would strike against another body, so as to set the latter in motion. The momentum of a body is composed of its weight, multiplied by its velocity. The quicker a body moves, the greater will be the force with which it will strike another body; so that a small light body may have a greater momentum than a heavy one, provided its velocity be sufficiently great. For instance, the momentum of an arrow shot from a bow is greater than that of a stone thrown by the hand. We know also, by experience, that the heavier a body is the greater is its force; if it acts in other respects under the same circumstances, therefore, the whole power or momentum of a body is composed of these two properties. But why should not these be added together, instead of being multiplied by one another? It is found, by experiment, that if the weight of a body be represented by the number 3, and its velocity also by 3, its momentum will be as 9; not 6, as would be the case were these figures added, instead of multiplied together. The same conclusion may very easily be deduced by reasoning. If two bodies, one of one pound weight, the other of two, have the same velocity, the moving force of the second, or its momentum, is double that of its first. If third body also of two pounds, move with three times the velocity of the second, its momentum, the weights in this case being equal, is three times that of the second. But the momentum of the second is twice that of the first, therefore the momentum of the third is six times that of the first. By thus dividing the process, and looking first to the effect of a change of the velocity, and afterwards to that of the change of weight, it becomes evident that these effects are to be multiplied together.

The *Re-action* of bodies is the next law to be explained. When a body in motion strikes against another body, it meets with resistance, the resistance of the body at rest will be equal to the blow struck by the body in motion; or, in philosophical language, action and re-action will be equal, and in opposite directions.

The most striking experiments on these subjects are made with elastic bodies. Elasticity is a property, by means of which bodies that are compressed return to their former state. If you bend a cane, as soon as it is at liberty, it recovers its former position; if you press your finger on your arm, as soon as you remove it, the flesh, by virtue of its elasticity, rises and destroys the impression. Of all bodies, those in the form of air or gas are the most eminent for this property. Hard bodies are in the next degree elastic: if two ivory or metallic balls be struck together, the parts at which they touch will be flattened, but no mark is perceptible, their elasticity instantly destroying all trace of it. If, however, a very small spot of ink be placed on one of the balls at the point of contact, it will be found after the contact to have spread, and will thus show that there has been compression. Soft bodies, which easily retain impressions, such as clay, wax, tallow, butter, &c., have very little elasticity.

The cause of elasticity is not well ascertained. Elasticity implies susceptibility of compression, and the suceptibility of compression depends upon the porosity of the bodies; for were there no pores or spaces between the particles of matter of which a body is composed, it could not be compressed. But we must not hence infer, that bodies whose particles are most distant from each other are most elastic. Elasticity implies not only susceptibility of compression, but the power of resuming its former state after compression. The pores of such bodies as ivory and metals are invisible to the naked eye; but it is well ascertained that gold, one of the most dense of all bodies, is externally porous, and that its pores are sufficiently large to admit water, under great pressure, to pass through them. In cork, sponge, and bread, the pores form considerable cavities; in wood, and many kinds of stone, when not polished, they are perceptible to the naked eye; whilst in ivory, metals, and most varnished and polished bodies, they cannot be discovered. To give an idea of the extreme porosity of bodies, Sir Isaac Newton conjectured that if the earth were so compressed as to be absolutely without pores, its dimensions might possibly not be more than a cubic inch.

Birds, in flying, strike the air with their wings; and it is the re-action of the air which enables them to rise or advance forwards. The force with which their wings strike against the air must equal the weight of their bodies, in order that the re-action of the air may be able to support that weight; the bird will then remain stationary. If the stroke of the wings be greater than is required merely to support the bird, the re-action of the air will make it rise; if it be less, it will descend. The lark sometimes remains with its wings extended, but motionless; in this state it drops rapidly into its nest. A bird expands his wings when he gives the stroke, the re-action of which is to impel him onward, and contracts them when in the opposite direction. The swimming of fishes is on the same principle; their fins are expanded and contracted in a like manner; and a man swimming strikes his hands out to produce the re-action which impels him forward, and turns them edgeways to lessen the effect of the contrary re-action. In rowing a boat, the oars are lifted out of the water every stroke, so as completely to prevent any re-action in a backward direction; and even in moving them through the air they are turned edgeways, or feathered, as it is called, from its resemblance to the action of the feathers of a bird in flying.

Let us now return to the subject of re-action, on we have some further observations to make. It is reaction being contrary to action which produces *reflected motion.* If you throw a ball against a wall, it rebounds; this return of the ball is owing to the re-action of the wall against which it struck, and is called reflected motion. A ball filled with air rebounds better than one stuffed with bran or wool, for the elasticity of the air re-acts after compression. If the ball be thrown pependicularly against the wall, it returns straight towards the hand, though the action of gravity draws it downwards before reaching it; but if thrown obliquely upwards it rebounds still higher. We use the term perpendicular in preference to the more familiar word straight, because straight is a general term for lines in all directions, which are neither curved nor bent, and is, therefore equally applicable to oblique or perpendicular lines. A perpendicular has always a reference to something towards which it is perpendicular; that is to say, that it inclines neither to the one side nor the other, but makes an equal angle on either side.

We shall now proceed to circular motion: this is the result of the action of two forces on a body, by one of which it is projected forward in a right line, whilst by the other it is continually directed towards a fixed point. For instance, if I whirl a ball fastened to my hand with a string, the ball will have a circular motion, because it is acted on by two forces, that I give it, which represents the force of projection, and that of the string, which confines it to my hand. If during its motion I were suddenly to cut the string, the ball would fly off in a straight line; being released from confinement to the fixed point, it would be acted on but by one force, and motion produced by one force is always in a right line. When a mop is trundled, the threads fly from the centre; but being confined to it at one end, they cannot part from it; whilst the water they contain is thrown off in straight lines. In the same way, the flyers of a windmill, when put in motion by the wind, would be driven straight forward in a right line, were they not confined to a fixed point, round which they are compelled to move. The point to which the motion of a small body, such as the ball with the string, is confined, becomes the centre of its motion, for it may be considered as moving in the same plane or flat surface. But when a body is not of a size or shape to allow of our considering every part of it as moving in the same plane, it revolves round a line, which is called the axis of motion. In a top, for instance, when spinning on its point, the axis is the line which passes through the middle of it, perpendicularly to the floor. The axle of the sails of a windmill is the axis of its motion. The centre of motion is not always in the middle of a body.

The middle point of a body is called its centre of magnitude, that is, the centre of its mass or bulk. Bodies have also another centre, called the centre of gravity, which shall be explained; but at present, we must confine ourselves for a short time longer to the axis of motion. This line remains at rest, while all the other parts of the body move round it; when a top is spun, the axis is stationary, whilst every other part is in motion round it. A top, it is true, has also generally a motion forwards, besides its spinning motion; and then no point within it can be at rest. But what is said of the axis of motion; that is to motion round a line, and not to that which a body may have at the same time in any other direction.

There is one circumstance in circular motion, which must be carefully attended to; it is, that the further any part of a body is from the axis of motion, the greater is its velocity: as you approach that line, the velocity of the parts gradually diminishes till you reach the axis of motion which is perfectly at rest. The extremities of the flyers of a windmill move over a much greater space than the parts nearest the axis of motion.

The force which confines a body to a centre, round which it moves, is called the *centripetal* force; and the power which impels a body to fly from the centre is called the *centrifugal* force; in circular motion these two forces balance each other; otherwise the revolving body would either approach the centre or recede from it, according as the one or the other prevailed. And should any cause destroy the centripetal force, the centrifugal force would impel the body to fly off from the centre. It would not, however, fly off in a right line from the centre, but in a right line in the direction it was moving at the instant of its release: if a stone whirled round in a sling, gets loose, it flies off at a tangent. This force would, therefore, with more propriety, be called the tangential than the centrifugal force, or rather, the inertia of the body which inclines it to move in the direction of the tangent is the tangential force. But motion in the direction of the tangent would remove the body further from the centre, and that part of its force which tends to produce motion thus away from the centre is called the centrifugal force.

If a ball be thrown in a horizontal direction, it is acted on by no less than three forces; the force of projection first given to it; the resistance of the air through which it passes; and the force of gravity which finally brings it to the ground. Gravity and the resistance of the air act continually; and as the whole effect produced by them is always so great as to overpower any force of projection we can communicate to a body, the latter is gradually overcome, and the body brought to the ground; but the stronger the projectile force, the longer will these powers be in subduing it. A shot fired from a cannon, for instance, will go much further than a ball thrown by the hand. Bodies thus projected described a curved line in their descent. If the forces of projection and of gravity both produced uniform motion, the ball would move in the diagonal of a parallelogram, but the motion produced by the force of projection by gravity is accelerated; and it is this acceleration which brings the ball sooner to the ground, and makes it fall in a curve instead of a straight line.

We have not taken notice of the resistance of the air, which much complicates these results in practice. The principles of its operation may easily be understood from the mode is which the the other forces act; but the degree and manner in which it modifies their effects cannot be shown without much difficulty and intricacy of explanation. It is, however, sufficiently plain that this resistance increases with the velocity of the ball, for the particles of air react on the ball in proportion to the stroke they receive from it; so that if the force of projection be doubled, the resistance of the air is doubled also; nor is this all—for in doubling the velocity of the ball, it passes through twice the quantity of air in the same time, and receives twice the resistance from each particle; the whole of the resistance must therefore be four times as great as in the first instance. And if the velocity of the ball be tripled, it will pass through three times the quantity of air; will strike each particle with three time the force, and receive three times the re-action; which, summed up, will make nine times the resistance.

The shortest mode of calculating the resistance is to multiply the velocity by itself; thus, if the velocity be three, multiply it by three, and the product will be nine. The product of a number multiplied by itself is called its square.

The curve line which a ball describes, if the resistance of the air be not taken into consideration, is called in geometry a *parabola*. But when the ball is thrown perpendicularly upwards, it will descend perpendicularly; because the force of projection, and that of gravity, are in the same line of direction.

We noticed the centres of magnitude and of motion, but we have not as yet explained what is meant by the centre of gravity. It is that point about which all the parts of a body exactly balance each other, in every position of the body; if therefore, that point is supported, the body will not fall. Were any other point of the body alone supported, the surrounding parts no longer balancing each other, the body would fall on the side at which the parts are heaviest; therefore, whenever the centre of gravity is unsupported, the body must fall. This sometimes happens with an over-loaded waggon winding up a steep hilll, one side of the road being higher than the other. It is dangerous, when a boat is in any risk of being upset, for the passengers to rise suddenly; this is owing to their raising the centre of gravity, and thus increasing the chance of throwing it out of the line of direction. When a man stands upright, the centre of gravity is supported by his feet. If he lean on one side, he will no longer stand firm. A rope-dancer performs all his feats of agility, by dexterously supporting his centre of gravity; whenever he finds himself in danger of losing his balance, he shifts the heavy pole, which he holds in his hands, in order to throw the weight towards the side that is deficient; and thus, by changing the situation of the centre of gravity, restores his equilibrium.

A stick is balanced on the point of the finger, by supporting its centre of gravity;* and it is for want of this support that spherical bodies roll down a slope. A sphere being perfectly round, can pass the slope but by a single point, and that point is not perpendicularly under the centre of gravity, which therefore is not supported. The centre of gravity, in this case, coincides with the centre of magnitude; but when one part of the body is composed of heavier materials than another part, the centre of gravity, being the centre of the weight of the body, will generally no longer correspond with the centre of gravity, though it may accidentally do so.

Bodies having a narrow base are easily upset, for if they are the least inclined, their centre is no longer supported. A person carries a single pail of water with great difficulty, owing to the centre of gravity being thrown much on one side, and the opposite arm is stretched out, to endeavour to bring it back to its original situation. But two pails, one hanging on each arm, are carried with much greater facility, because they balance each other.

When two bodies are fastened together by a rod, they are to be considered as forming but one body.—If the two bodies be of equal weight, the centre of gravity will be in the centre of the line which unites them, but if one be heavier than the other, the centre of gravity will be proportionably nearer the heavy body than the light one.

ON THE MECHANICAL POWERS.

THE mechanical powers are six in number, one or more of which enters into the composition of every machine. The *lever*, the *pulley*, the *wheel* and *axle*, the *inclined plane*, the *wedge*, and *screw*.

In order that we may understand the power of a machine, there are four things which claim our consideration.

1st. The power that acts: this consists in the effect of men or hosses—of weight, springs, steam, &c.

2nd. The resistance which is to be overcome by the power; this is generally a weight to be moved. The effect of the power acting in the manner which in each particular cast it is applied, must always be superior to the resistance, otherwise the machine could not be put in motion. For instance, were the resistance of a carriage equal to the strength of the horses employed to draw, they would not be able to make it move.

3rdly. We are to consider the centre of motion, or, as it is termed in mechanics, the fulcrum, which means a prop; this is the point about which all parts of the body move: and,

Last. The respective veloicities of the power, and of the resistance.

We shall first examine the power of the lever. The lever is an inflexible rod or beam, that is to say, one which will not bend in any direction. For instance, the steel rod to which a pair of scales is suspended is a lever, and the point by which it is suspended, called the prop or fulcrum, is also the centre of motion. The two parts of a lever, divided by a fulcrum, are called its arm. Now, both scales being empty, they are of the same weight, and consequently balance each other. We have previously stated, that when two bodies of equal weight were fastened together, the centre of gravity would be in the middle of the line that connected them; the centre of gravity of the scales must, therefore, be in the middle between them, as the fulcrum is, and this being supported, the scales balance each other.

We must bear in mind, that if a body be suspended by that point in which the centre of gravity is situated, it will remain at rest in any position indifferently;

which is not the case with this pair of scales, for when we hold them inclined, they instantly regain their equilibrium; the reason of this is, that the centre of suspension, instead of exactly coinciding with that of gravity, is a little above it; if, therefore, the equilibrium of the scales be disturbed, the centre of gravity moves in a small circle round the point of suspension, and is therefore forced to rise, and the instant it is restored to liberty it descends, and resumes its situation immediately below the point of suspension, when the equilibrium is restored. It is this property which renders the balance so accurate an instrument for weighing goods. If the scales contain different weights, the centre of gravity will be re moved towards the scale which is heaviest, and being no longer supported, the heaviest scale will descend. The fulcrum of the balance is moveable; the lever may be taken off the prop and fastened on in another point, which then becomes the fulcrum. In this case the equilibrium is destroyed; the longest arm of the lever is the heaviest, and descends. The centre of gravity is not supported because it is no longer immediately below the point of suspension; but if we can bring the centre of gravity immediately below the point, as it is now situated, the scales will again balance each other. Now if a heavy weight be placed in the scale suspended to the shortest arm of the lever, and a lighter one into that suspended by the longest arm, equilibrium will be restored. It is not, therefore, impracticable to make a heavy body balance a light one; and by this means, an imposition in the weight of goods is very frequently effected by dishonest dealers, as a weight of ten or twelve ounces might thus be made to balance a pound of goods. An ingenious balance, called a steelyard, has been invented on the principle that a weight increases in effect, in proportion to its distance from the fulcrum. In this machine, for instance, a single pound weight answers the purpose of weighing any quantity of goods, simply by moving it along the lever; for in proportion as it recedes from the fulcrum, it will balance five, ten, twenty, fifty, or perhaps even as many as a hundred pounds weight. The hook by which the instrument is suspended, forms the fulcrum; it is, for instance, two inches distant from the basin which is to contain the articles to be weighed, while the opposito arm of the lever extends two feet; a small weight is suspended to it, and the graduations on the lever indicate the different powers of this weight, according to the situation which it occupies on the long arm of the lever; when pushed to the extremity, a weight of five pounds is equivalent to sixty pounds placed in the basin. The same steelyard, when suspended by a second hook, which divides the lever with less inequality, and corresponds with another scale of graduation, is used for weighing smaller quantities of goods, and the same weight, when hung at the extremity, may be equal to twenty pounds placed in the basin.

Let us now return to the balance, and divesting it of the basins, consider the lever simply. In this state the fulcrum is no longer in the line of direction of the centre of gravity, but it is, and must ever be, the centre of motion, as it is the only point which remains at rest while the other parts move about it. When a lever is put in motion, the longest arm, or acting part of the lever, must move with greater velocity than the shortest arm, or resisting part of the lever, because it is farthest from the centre of motion. When two boys ride on a plank drawn over a log of wood, the plank becomes a lever, the log which supports it the fulcrum, and the two boys the power and the resistance at each end of the lever. When the boys are of equal weight, the plank must be supported in the middle to make the two arms equal; if they differ in weight, the plank must be drawn over the prop so as to make the arms unequal, aud the lightest boy to be placed at the extremity of the longest arm, in order that the greater velocity of his motion may compensate for the superior gravity of his companion, so as to render their momentums equal. But we know that the action of the power must be greater than the resistance, in order to put the machine in motion. For this purpose, each boy at his descent touches the ground with his feet, and the support he receives from it diminishes his weight, and enables his companion to raise him; thus each boy alternately represents the power and the weight, and the two arms alternately perform the junction of the acting and the resisting part of the lever.

A lever, in moving, describes the arc of a circle, for it can move only around the fulcrum or centre of motion. It would be impossible for one child to rise perpendicularly, or for the other to descend in a straight line; they describe arcs of their respective circles; and you may judge from the different dimensions of the circle how much greater the velocity of the little child must be than that of the bigger one. Enormous weights may be raised by levers of this description, for the longer the acting part of the lever in comparison to the resisting part, the greater is the effect produced by it; because the greater is the velocity of the power compared to that of the weight. You may have seen a heavy snow-ball thrown over, by thrusting the end of a long stick beneath the ball, and resting it against a log of wood, or any other object which may give it support, near the end in contact with the snow-ball. The stick in this case is a lever; the support, the prop or fulcrum; and the nearer the latter is to the residence, the more easily will the power be able to move it.

There are three different kinds of levers; in the first, which comprehends the several levers we have been describing, the fulcrum is between the power and the weight. When the fulcrum is situated equally between the power and the weight, as in the balance, the power must be greater than the weight, in order to move it; for nothing can in this case be gained by velocity. The two arms of the lever being equal, the velocity of their extremities must be so likewise. The balance is, therefore, of no assistance as a mechanical power, but it is extremely useful to estimate the respective weights of bodies. But when the fulcrum of a lever is not equally distant from the power and the weight, and that in amount, though greater in effect, the power acts at the extremity of the longest arm, it may be less than the weight, its deficiency being compensated by its superior velocity; as we observed in the case of the boys and the *see-saw*. Therefore, when a great weight is to be raised, it must be fastened to the shortest arm of the lever, and the power applied to the longest arm; but if the case will admit of putting the end of the lever under the weight, no fastening will be required, as you may perceive by stirring the fire. The poker is a lever of the first kind; the point where it rests against the bars of the grate, whilst stirring the fire, is the fulcrum; the shortest arm, or resisting part of the lever, is imployed in lifting the weight, which is the coals, and the hand is the power applied to the longest arm, or acting part of the lever. A pair of scissors is an instrument composed of two levers united in one common fulcrum; the point at which the two levers are screwed together is the fulcrum; the handles to which the power of the fingers are applied, are the extremities of the acting part of the levers, and the cutting part of the scissors, are the resisting parts of the levers; therefore, the longer the longer the handles, and the shorter the points of the scissors, the more easily will they cut. Thus, when pasteboard, or any hard substance is to be cut, that part of the scissors nearest the screw, or rivet, is used. Snuffers, and most kinds of pincers, are levers of a similar description, the great force of which consists in the resisting part of the lever being very short in comparison of the acting part.

In levers of the second kind, the weight, instead of being at one end, is situated between the power and the fulcrum. In moving it, the velocity of the power must necessarily be greater than that of the weight, as it is more distant than the centre of motion. Let us take, for example, a snow-ball moved by means of a lever of the second order, as well as by one of the first. The end of the stick that is thrust under the ball rests on the ground, which becomes the fulcrum; the ball is the weight to be moved, and the power, the hands applied to the other end of the lever. In this instance, there is an immense difference in the length of the arms of the lever, the weight being almost close to the fulcrum, and the advantage gained is proportional. Fishermen's boats are thus raised from the ground to be launched into the sea, by means of slippery pieces of board, which are thrust under the keel. The most common example that we have of levers of the second kind is in the doors of our apartments; in these the hinges represent the fulcrum, the hand, the power applied to the other end of the lever, and the door, or rather its inertia, is the weight which occupies the whole of the space between the power and the fulcrum.

The whole weight and inertia of the door may be regarded as collected into its centre of gravity; that is to say, the resistance of the door is the same that would be offered by a force equal to the inertia of the door, and passing through its centre of gravity. Another very common instance is found in an oar: the blade is kept in the same place by the resistance of the water, and becomes the fulcrum; the resistance is applied where the oar passes over the gunwale of the boat, and the hands at the handle are the power. Nut-crackers are double levers of this kind: the hinge is the fulcrum, the nut the resistance, and the handle the power.

In levers of the third kind, the fulcrum is also at one of the extremities, the weight or resistance at the other, and it is now the power that is applied between the fulcrum and the resistance. Thus the fulcrum, the weight, and the power, each in its turn occupies some part of the lever between its extremity. But in this third kind of lever, the weight being farther from the centre of motion than the power, the difficulty of raising it, instead of being diminished, is increased. Levers of this description are used when the object is to produce great velocity. The aim of mechanics, in general, is to gain force, by exchanging it for time; but it is sometimes desirable to produce great velocity by an expenditure of force. The treddle of a common turning lathe affords an example of a lever of the third kind employed in gaining time, or velocity, at the expense of force. A man, in raising a long ladder perpendicularly against a wall, cannot place his hands on the upper part of the ladder; the power, therefore, is necessarily placed nearer the fulcrum than the weight, for the hands are the power, the ground the fulcrum, and the ladder the weight; which, as in the case of a door, may be considered as collected in the centre of gravity of the ladder, about half way up, and consequently beyond the point where the hands are applied. Nature employs this kind of lever in the structure of the human frame. In lifting a weight with the hand, the lower part of the arm becomes a lever of the third kind; the elbow is the fulcrum; the muscles which move the arm, the powers; and as these are nearer to the elbow than the hand is, it is necessary that the power should exceed the weight to be raised.

It may perhaps be matter of wonder that Nature should have furnished us with such levers, but the disadvantage is more than compensated by the convenience resulting from the structure of the arm. It is of more consequence that we should be able to move our limbs nimbly, than that we should be able to overcome great resistance, for it is comparatively seldom that we meet with great obstacles, and when we do, they can be overcome by art. Besides, the Creator has endowed the muscular fibres with prodigious strength, so that upon the whole, this kind of lever is best adapted to enable the arm to perform its various functions.

We will now direct our attention to the *Pulley*, which is the second mechanical power. It is a circular flat piece of wood or metal, with a string running in a groove round it, by means of which a weight may be pulled up. Thus pulleys are used for drawing up curtains, the sails of a ship, &c. When the pulley is fixed, it does not increase the power to raise the weight. It is evident, therefore, that the power must be greater than the weight, to move it. A fixed pulley is useful, therefore, only in altering the direction of the power, and its most frequent application is to make us draw up a weight by drawing down the string connected with the pulley. But the moveable pulley affords mechanical assistance. The hand which sustains a cask by means of a cord going over the moveable pulley, does it more easily than if it held the cask suspended to a cord without a pulley; for the fixed hook, to which one end of the cord is fastened, bearing one half of the weight of the cask, the hand has only the other half to sustain. Now it is evident, that the hook affords the same assistance in raising as in sustaining the cask, so that the hand will only have one half the weight to raise. But observe, that the velocity of the hand must be double to that of the cask; for in order to raise the latter one inch, the hand must draw the two strings one inch each; the whole string being shortened two inches, while the cask is raised only one. Thus the advantage of a moveable pulley consists in dividing the difficulty; twice the length of string, it is true, must be drawn, but only half the strength is required which would be necessary to raise the weight without such assistance: so that the difficulty is overcome in the same manner as it would be by dividing the weight into two equal parts, and raising them successively. It may perhaps be objected to pulleys, that a longer time is required to raise a weight with their aid than without it; that is true; for it is a fundamental law in mechanics, that what is gained in power is lost in time; this applies not only to the pulley, but to the lever, and all the other mechanical powers. It would be wrong, however, to suppose that the loss was equivalent to the gain, and that we derive no advantage from the mechanical powers; for since it is entirely beyond our power to augment our bodily strength, it must be admitted that science is of the greatest utility, that enables us to reduce the resistance or weight of any body to the level of our strength. This we accomplish by dividing the resistance of a body into parts which we can successively overcome: and if it require a sacrifice of time to attain this end, we must be very sensible how very advantageously it is exchanged for power. The greater the number of pulleys connected by a string, the more easily the weight is raised, as the difficulty is divided amongst the number of strings, or rather of parts into which the string is divided by the pulleys. Several pulleys thus connected form what is called a system, or tackle of pulleys. They may be seen suspended from cranes, to raise goods into warehousess, and in ships, to draw up the sails. Here both the advantages of an increase of power and a change of direction are united; for the sails are raised up the masts by the sailors on deck, from the change of direction which the pulley effects; and the labour is facilitated by the mechanical power of a combination of pulleys. Pulleys are frequently connected, both for nautical and other purposes: but in whatever manner pulleys are connected by a single string, the mechanical power is the same in its principle.

The wheel and axle is the third mechanical power. Let us suppose the weight to be a bucket of water in a well, which is to be raised by winding the rope, to which it is attached, round the axle; if this be done without a wheel to turn the axle, no mechanical assistance is received. The axle without a wheel is as impotent as a single fixed pulley, or a lever, whose fulcrum is in the centre; but add the wheel to the axle, and you will immediately find the bucket is raised with much less difficulty. The axle acts the part of the shorter arm of the lever, the wheel that of the longer arm. The velocity of the circumference of the wheel is as much greater than that of the axle, as it is farther from the centre of motion; for the wheel describes a large circle in the same space of time that the axle describes a small one, therefore the power is increased in the same proportion as the circumference of the wheel is greater than that of the axle. If the velocity of the wheel were twelve times greater than that of the axle, a power nearly twelve times less than the weight of the bucket would be able to raise it. Instead of a wheel, there is more commonly attached to the axle a crooked handle, which answers the same purpose. For the branch of the handle which is united to the axle represents the spoke of a wheel, and is as effectual as an entire one; the other branch affords no mechanical aid, merely serving as a handle to turn the wheel. Wheels are a very essential part of machines. They are employed in various ways; but when fixed to the axle, their mechanical power is always the same; that is, as the circumference of the wheel exceeds that of the axle, so much will the energy of the power be increased. In mills and manufactories, no person sees, without admiring, the immense wheel, the revolution of which puts the whole of the machinery into motion; and though so great an effect is produced by it, a horse or two has sufficient power to turn it; but the steam-engine is both the most powerful and the most convenient mode of turning the wheel. We have the advantage sometimes of a gratuitous force, such as a stream of water, to turn the wheel of a water-mill; and the wind which acts upon the sails of a windmill. One of the great benefits resulting from the use of machinery is, that it gives us, as it were, a sort of empire over the powers of nature, and enables us to make them perform that labour which would otherwise fall to the lot of man. When a current of wind, a stream of water, or the expansive force of steam performs our task, we have only to superintend and regulate their operations.

The fourth mechanic power is the *Inclined Plane.* This is nothing more than a gentle slope or declivity, frequently used to facilitate the drawing up of weights. It is not difficult to understand, that a weight may with much greater ease be drawn up a slope than it can be raised the same height perpendicularly. But in this as well as the other mechanical powers, the facility is purchased by a loss of time.

The *Wedge*, which is the next mechanical power, is composed of two incined planes; it is frequently used by wood-cutters to cleave wood. The resistance consists in the cohesive attraction of the wood, or any other body which the wedge is employed to separate; and the advantage gained by this power is in proportion of half its width to its length. The wedge, however, acts principally by being struck, and not by mere pressure: the proportion stated is that which expresses its power when acting by pressure only.

All cutting instruments are constructed upon the principle of the inclined plane, or the wedge. Those that have but one edge sloped, like the chisel, may be referred to the inclined plane; whilst the axe, the hatchet, and the knife (when used to chop or split asunder), act on the principle of the wedge. But a knife cuts best when drawn across the substance it is to divide, as it is used in cutting meat, for the edge of a knife is really a very fine saw, and therefore acts best when used like that instrument.

The *Screw* which is the last mechanical power, is much more complicated than the others. It is composed of two parts,—the screw and the nut. The screw is a cylinder, with a spiral protuberance coiled round it, called the thread, the nut is perforated to contain the screw; and the inside of the nut has a spiral groove, made to fit the spiral spiral thread of the screw; just like the lid of a box which screws on. The handle which projects from the nut is a lever, without which the screw is never used as a mechanical power. The nut, with a lever attached to it, is commonly called a winch. The power of the screw complicated as it appears, is referable to one of the most simple of the mechanical powers, the inclined plane. If a slip of paper be cut in the form of an inclined plane, and wound round a pencil, which will represent the cylinder, it will describe a spiral line corresponding to the spiral protuberance of the screw. The nut then ascends an inclined plane, but ascends it in a spiral instead of a straight line. The closer the thread of the screw, the more easy is the ascent, but the greater are the number of revolutions the winch must make; so that we return to the old principle—what is saved in power is lost in time. The power of the screw may be increased also, by lengthening the lever attached to the nut; it is employed either for compression, or to raise heavy weights. It is used in cider and wine presses, in coining, bookbinding, and for a variety of other purposes.

All machines are composed of one or more of the six mechanical powers we have been examining and explaining. One more remark must be made relative to them, which is, that friction in a considerable degree diminishes their force. Friction is the resistance which bodies meet with in rubbing against each other. There is no such thing as perfect smoothness or evenness in Nature. Polished metals, though they wear that appearance, more than any other bodies, are really far from possessing it; and their inequalities may frequently be perceived through a good magnifying glass. When, therefore, the surfaces of the two bodies come into contact, the prominent parts of the one will often fall into the hollow parts of the other, and occasion more or less resistance to motion. In proportion as the surfaces of bodies are well polished, the friction is diminished; but it is always considerable, and it is usually computed to destroy one-third of the power of a machine. Oil or grease is used to lessen friction; they act as a polish, by filling up the cavities of the rubbing surfaces, and thus making them slide more easily over each other. It is for this reason that wheels are greased, and the locks and hinges of doors oiled. In these instances, the contact of the rubbing surfaces is so close, and the rubbing so continual, that, notwithstanding their being polished and oiled, a considerable degree of friction is produced. It is a remarkable circumstance, that there is generally less friction between two bodies of different substances, than of the same. It is on this account that the holes in which the spindles of watches work are frequently made of jewels; and that when two cog-wheels work into one another, the cogs of the one are generally made of wood, and the other of metal.

There are two kinds of friction; the one occasioned by the sliding of the flat surface of a body, the other by the rolling of a circular body. The friction resulting from the first is much the most considerable; for great force is required to enable the sliding body to overcome the resistance which the asperities of the surface in contact oppose to its motion, and it must be lifted over, or break through them; whilst, in the other kind, the friction is transferred to a small surface, and the rough parts roll over each other with comparative facility; hence it is, that wheels are often used for the sole purpose of diminishing the resistance of friction. Where, in descending a steep hill, we fasten one of the wheels, we decrease the velocity of the carriage by increasing the friction, that is to say, by converting the rolling friction of one of the wheels into the dragging friction; and when castors are put to the legs of a table, the dragging is converted into the rolling friction.

The great fly-wheel, which is frequently attached to steam-engines and other large machines, acts, in the first instance, as a heavy weight to impel their uncontrolled motion. However paradoxical this mode of improving machinery may appear to be, it is nevertheless of great advantage. The motion of a machine is always more or less variable, owing to the irregularity, both of the power which works it, and of the resistance which it has to overcome. Whether the power consists in wind, water, steam, or the strength of animals, it cannot be made to act with with perfect regularity, nor can the work which the machine has to perform be always uniform. Yet in manufactures, and most cases in which machinery is employed, uniformity of action is essentially requisite, both in order to prevent injury to the machine, and imperfection in the work performed. A fly-wheel, which is a large heavy wheel attached to the axis of one of the principal wheels of the machinery, answers this purpose, by regulating the action of the machine: by its weight it diminishes the effect of increased action, and by its inertia it carries on the machine with uniform velocity, when the power transiently slackens; thus, by either checking or impelling the action of the machine, it regulates its motion so as to render it tolerably uniform.

There is another circumstance which we have already noticed as diminishing the motion of bodies, and which greatly affects the power of machines: this is the resistance of the medium in which a machine is worked. All fluids, whether of the nature of air, or of water, are called mediums; and their resistance is generally proportioned to the density: for the more matter a body contains, the greater resistance it will oppose to the motion of another striking against it. It is, therefore, more difficult to work a machine under water than in the air. If a machine could be worked in *vacuo*, and without friction, it would be perfect; but this is unattainable. A considerable reduction of power must, therefore, be allowed for the resistance of the air.

While on this subject, we may be allowed to make a few observations on tools. The difference between a *tool* and a *machine* is not capable of very precise distinction; nor is it necessary, in a popular explanation of those terms, to limit very strictly their acceptation. Various operations occur in the arts, in which the assistance of an addditional hand would be a great convenience to the workman, and in these cases, tools of the simplest construction come to his ready aid. The simpler machines are often only one or more tools placed in a frame, and acted on by any moving power. In pointing out the advantages of tools, we shall give an example of one of the simplest.

To arrange twenty thousand needles thrown promiscuously into a box, mixed and entangled with each other in every possible direction, in such a form that they shall be all parallel one with another, would at first sight appear a most tedious and difficult operation; in fact, if each needle were to be separated individually, many hours must be occupied in the process. Yet this is an operation which must be performed many times in the manufacture of needles; and it is accomplished in an incredibly short space of time—a few minutes—by a very simple tool; nothing more being requisite than a small flat tray of sheet iron, slightly concave at the bottom. The needles are placed in it, and shaken in a peculiar manner, by throwing them up a very little, and giving at the same time a slight longitudinal motion to the tray. The shape of the needles assist their arrangement; for if two needles cross each other, (unless, which is exceedingly improbable, they happen to be precisely balanced,) they will, when they fall on the bottom of the tray, tend to place themselves side by side, and the hollow form of the tray assists this disposition. As they have no projection on any part to impede this tendency, or to entangle each other, they are, by continually shaking, arranged lengthwise in three or four minutes. The direction of the shake is now changed; the needles are but little thrown up, but the tray is shaken edgeways; the result of which is, that in a minute or two, the needles, which were previously arranged endways, become heaped up in a wall, with the ends against the extremity of the tray. They are now removed by hundreds at a time, by raising them with a broad iron spatula, on which they are retained by the fore-finger of the left hand. During the progress of the needles towards their finished state, this parallel arrangement must be repeated several times; and, unless some such cheap and expeditious method had been devised, the expense of manufacturing needles would have been considerably increased.

Another process in the art of making needles furnishes an example of one of the simplest contrivances which can come under the denomination of a *tool*, the efficiency of which, for the purpose, required no one will deny. After the needles have been arranged in the manner we have been describing, it is necessary to separate them into two parcels, in order that their points may all be placed in one direction. This is for the most part done by women and children. The needles are placed sideways in a heap, on a table or bench, in front of each operator, just as they are arranged by the process above described. From five to ten are rolled towards this person by the fore-finger of the left hand; this separates them a very small space from each other, and each in its turn, is pushed lengthwise to the right or to the left, according as its eye is on the right or the left hand. This is the usual process, and in it every needle passes individually under the finger of the operator. A small alteration expedites the process considerably; the child puts on the fore-finger of its right hand a small cloth cap, or finger-stall, and rolling out of the heap from six to twelve needles, he keeps them down by the fore-finger of the left hand, whilst he presses the fore-finger of the right hand gently against their ends: those which have the points towards the right hand stick into the finger-stall; and the child removing the finger of the left hand, slightly raises the needles sticking into the cloth, and then pushes them towards the left side. Those needles which had their eyes on the right hand do not stick into the finger-cover, and are pushed away to the heap on the right side previously to the repetition of this process. By means of this simple and ingenious contrivance, each movement of the finger from one side to the other, carries five or six needles to their proper heap; whereas, in the former method, frequently only one was moved, and rarely more than two or three were transported at one movement to their place.

PNEUMATICS.

The science of Pneumatics treats of the density, pressure, and elasticity of the air, and the effects which they produce.

The air is the fluid in which we live and breathe: it entirely envelopes the globe, and extends to an unknown height above its surface. It is, together with the clouds and vapours that float in it, called the *atmosphere*.

Anciently, the air was supposed to be destitute of weight, and Galileo was the first who proved, by experiments, the fallacy of this supposition; and it is now sufficiently manifest, that, like all other fluids, it presses upon bodies in proportion to the depths they are immersed in it; and that the pressure is in every direction, or on all sides of such bodies. It differs from most other fluids in the four following particulars: 1. It can be compressed into a much less space than it naturally possesses. 2. It cannot be congealed or reduced to a solid state. 3. It is of a different density in every part upwards from the earth's surface, decreasing in its weight as its distance from the earth increases. 4. Its elasticity, or the force with which it springs, is equal to the incumbent weight.

The air being perfectly invisible, and affording no resistance to the touch, it is not surprising that, according to vulgar apprehension, it should not be considered as a solid substance, and yet that it possesses weight, and great power of resistance to other bodies, many simple experiments may be devised to prove. A bladder, open at the aperture of the neck, may have its sides pressed together with the greatest ease; but if a bladder be filled by blowing air into it, and a string tied fast round its neck, it becomes impossible to press the sides together without bursting, and a very slight alteration of its figure requires considerable pressure. This resistance evidently proves that air is matter.

It is the great transparency of the air, which, in the common acceptation of the term, renders it invisible; but the blue colour of the sky may be considered as the colour of the air, for this blueness is occasioned by the light reflected from the air, and the particles it contains. If, however, the atmosphere was absolutely transparent, it would reflect no light; every object would then be in total darkness, except it received the direct rays of the sun, and the stars would be visible at noonday.

The pressure of the atmosphere is removed for philosophical purposes by means of the air-pump. With this machine, a great variety of interesting experiments may be performed in proof of the properties of the atmosphere; without it, indeed, pneumatics would scarcely deserve the name of a science.

When the gravity of the air had once become known, it may be thought that it could not have been very difficult to account for some of its more remarkable effects, such as the ascent of water in the body of a pump. The contrary, however, appears to have been the case. Some Italian artists having received orders to construct a common pump for the purpose of raising water to the height of 50 or 60 feet, found, to their astonishment, that about 33 feet was the limit to which the water would rise. Galileo was applied to for an examination of this circumstance; and as he had accepted the current opinion, that the only reason why water rose at all in pumps was nature's abhorrence of a vacuum, so to this inquiry he answered, that nature did not entertain the horror of a vacuum beyond 33 feet! Galileo had afterwards reason to suppose that he had not given a very philosophical answer to the question put to him, but Torricelli, a pupil of his, was the first who conjectured that water is elevated in pumps by the pressure of the exterior air; and that the amount of this pressure could counterbalance no more than a column of water thirty-three feet high. He instituted an experiment that at once verified his conjecture, and proved the origin of that important invention, the barometer. He took a glass tube of about three feet in length, hermetically sealed at one end, and open at the other; he filled it with pure mercury, and stopping the orifice with his finger, he reversed the tube, and placed the open end in a vessel full of the same mercury. He had no sooner removed his finger than the column of mercury, which was about thirty-inches long, was reduced to the length of about twenty-eight inches. This height being to that of thirty-three feet, in the inverse ratio of the densities of water and mercury, he concluded that, as he had conjectured, it was the pressure of the air which caused both water and mercury to rise until an equilibrium was produced. The experiment thus tried is called the Torricellian experiment, and the space left at the top of the tube, the Torricellian vacuum. It is the nearest approach to a perfect vacuum which the art of man can form, and is much superior to that of the best air-pump.

The pressure of the atmosphere is not always the same at the same place. These changes take place chiefly in countries at a distance from the equator. In Great Britain the barometer has been known to vary more than an inch in a few hours. Supposing the surface of a middle sized man, equal to fourteen and a half feet square, the pressure upon him, when the atmosphere is lightest is equal to thirteen and a half, and when heaviest, it is about fourteen and one third tons. The immense pressure we sustain does not impede our motions, because the pressure on one side is balanced by an equal pressure on the opposite side, nor is it capable of crushing the human frame, because the elastic force of the air, or some other elastic fluid within the body, is just sufficient to resist every injurious effect. So far from the pressure of of the atmosphere being a disadvantage it is indispensable; and we find that our frame is braced, and that we are never more alert and active than in clear and fine weather when the mercury stands highest, and consequently the pressure of the atmosphere is greatest; on the contrary, when the mercury falls and the weight of the air diminishes, we feel listless and uncomfortable.

PNEUMATICAL INSTRUMENTS.

Ever since it was observed that the height of a column of mercury, sustained in a tube by the pressure of the atmosphere, varied in height at different times, and that these variations were accompanied or followed by changes in the weather, such an instrument has been applied to meteorological purposes, under the name of the *barometer*.

The *Thermometer* is a chemical rather than a pneumatical instrument, but it claims notice as a useful appendage to the barometer. All substances expanding with an increase of their temperature, it is obvious that, under the same pressure of the atmosphere, the mercury in the barometer will be highest when the heat is greatest; a correction is therefore necessary for this source of error, before the exact effect of the pressure can be ascertained, and this is accomplished by means of the thermometer, or instrument for measuring the degrees of heat, joined with a knowledge of the rate at which the mercury in the barometer expands.

The state of the atmosphere, with respect to dryness or moisture, is measured by an instrument called an *hygrometer* or *hygroscope.* Various substances are susceptible of considerable alterations in weight or length, by attracting or parting with moisture; such substances are called *hygroscopic.*

The quantity of water returned by the atmosphere to the earth in the state of rain, is ascertained by an instrument called a *pluviometer* or *rain-guage.* It is usually made in the form of a jar, or hollow cylinder, with a funnel at the top of it. They are made of various sizes, but in general, if the ring be twelve inches in diameter it may not be considered too large.

WINDS.

AIR, when in progressive motion, is called wind, in which state it becomes one of the most powerful agents in nature—its force increasing nearly as the square of its velocity, and its velocity often being prodigious.

The natural tendency of the atmosphere, as of all other bodies, is to remain in a state of rest; and if this tendency were not unceasing causes, this fluid would everywhere be stagnant, and at the same elevation would have the same temperature. The density of the air is diminished by an increase of temperature,—that is, the more it is, heated, the more space it takes up, and consequently the less its pressure, bulk for bulk, on the surrounding air. This being the case, and the contrary, when its density is increased by cold, being equally true, it follows that when any particular tract of air is heated or cooled more than the rest, the heavy parts will press it upwards, and occupy its place; and the atmosphere will not be at rest, until the equilibrium of its parts, in heat and density take place.

Dr. Franklin was the first who observed, that winds originate at the precise point towards which they blow. Thus, in going out of a large town in winter, a wind is met in every point of the compass, because the air in the town being rarified by so many fires and the breathing of the people, is forced to ascend by the pressure of the colder and denser air of the country on all sides of it. Partial changes of temperature, are, therefore, the chief general causes of all winds, and it is the business of man, with respect to this subject, to discover where, and in what degree, they occur, in order to account for the individual phenomena. The attraction of the sun and moon is on good grounds supposed to occasion wind, and it is calculated from the theory of gravitation, that the influence of these bodies in their daily motions, is sufficient to produce a continual east wind about the equator. When, therefore, attraction coincides with heat to produce an aerial tide, the combined effect may be very considerable. Whatever may be the influence of the sun and moon in occasioning winds by their attraction, that of the moon will be the greatest, for the same reason, and in the same proportion, that her influence is the greatest in producing the tides of the ocean. The most likely periods of the year to have high winds are the two equinoxes; and storms are more frequent at the time of new and full moon, especially those new and full moons that happen about the equinoxes.

The most remarkable of all the winds is called the *Trade-wind;* and as it evidently follows the course of the sun, it appears undeniable that the sun is the cause of it. This wind, about the middle part of its track, always blows either exactly or very nearly from the east; but even when the sun is at, or very near the equator, towards its northern boundary, it deviates more and more from the east towards the south. The manner in which the sun causes the trade wind, seems to be generally agreed upon.

Of the periodical winds, the most remarkable are those called the *Monsoons*, which blow for six months in one direction, and for six months in an opposite one. They are confined to the tropics, and are deviations from the regularity of the trade-winds of half a year's duration, because for half the year, the monsoons mostly coincide with the general trade-wind. The origin appears to be owing to the circumstances of the different degrees of heat communicated to the air by water, and particular tracts of land. From October till April, the monsoon sets in from the north-west to the south-east, opposite to the general course of the trade-wind on the other side of the line; and here also the general trade-wind resumes its usual course during the other months, which constitute the winter seasons in these regions.

Some of the variable winds which prevail in warm countries, are distinguished by particular names, and possess very extraordinary qualities. The *Harmattan* is a wind which blows from the interior parts of Africa towards the Atlantic ocean. It prevails in the months of December, January, and February; but its duration is uncertain, sometimes only a day or two, sometimes as many as fifteen or sixteen. It is always accompanied with a fog that robs the sun of his splendour. Such is the extreme dryness of this wind that it withers the whole vegetable creation. The human body is much affected with the harmattan, which if it continues five or six days, the scarf skin peels off, and though the air is cool, it excites a troublesome sensation of pricking heat. Notwithstanding, the harmattan is salubrious, stopping infection, and removing the virulence of distemper with an efficacy not less remarkable than its other qualities.

The *Sirocco* is a south wind, which generally blows in Italy and Dalmatia, every year about Easter. It is supposed to blow from the burning deserts of Africa.—During its continuance, the inhabitants of the countries where it prevails, never venture out of doors unless compelled by necessity, but closing every aperture that can admit the air into their houses, they keep continually sprinkling their apartments with water. In Sicily this wind seldom continues longer than thirty-six or forty hours; in Italy it sometimes continues twenty days, but is not so severe. It is commonly succeeded by the tramontane, or north wind, which in a short time restores the vigour of languishing nature.

The *Samiel*, or mortifying wind of the deserts cannot, it is said, be breathed without destruction. The camels are reported to be instinctively aware of its approach, and to thrust their heads under the sand till it is blown over, which is commonly in a few minutes. The travellers throw themselves flat on the ground to avoid it; but if any one breathe it, his whole body becomes immediately mortified.

Whirlwinds are generally supposed to be occasioned by the conveyance of winds from all parts to one point, by some extraordinary rarefaction of the air at that point. The currents acquire by their conflict at the place of meeting, and the velocity with which the rarified air rushes upwards, a centrifugal force, which causes them to recede from the axis of rotation.

A *Tornado* is a whirlwind upon a large scale, being produced by the same causes: it is the whirlwind of tropical regions, and its effects are often tremendous. A moist vapour usually attends a tornado, the path of which is marked as if with rain.

Hurricane is another term for a storm wind, seldom seen, in its most terrific form, except in tropical climates. It is occasioned by the struggle of opposite winds, but does not, like the tornado, shift through all the points of the compass. It generally comes on with a northerly wind, and after veering to the east, it ceases; but the change is effected with such sudden impetuosity, that no ship can veer with it; whence it happens that the sails and yards are carried away, and sometimes the masts themselves twisted off. Of hurricanes it is usually observed that they happen either on the day of the full, change, or quarter of the moon.

It would be an interesting speculation to attempt the developement at large of the purpose effected by the winds; but in this place it must suffice to observe generally, that their cessation would accomplish the immediate destruction of animated existence. It is the atmosphere's ceaseless propensity to motion, from every cause that varies its density, and the universal prevalence of such causes, that carries off noxious effluvia as it is produced, to parts where, by chemical operations in the laboratory of nature, it is absorbed or regenerated, and the whole mass of atmosphere preserved from corruption. And when we turn from this point of view to another, we find the services of the winds almost equally important in ameliorating the fervour of a vertical sun, and in short, equalising the temperature over the whole globe. When these salutary and universal benefits are considered, the transient and partial effects of storms, especially when regarded as arising out of the rapidity with which the winds perform their office, can be regarded only as a slight sacrifice to the general good.

THE WEATHER.

A knowledge of the approaching changes of the weather is of so much utility and importance to a great part of mankind and of convenience to all, that it may seem surprising every indication of change observation has yet furnished, has not been accumulated, and reduced into one system. It is true, however, that with respect to this, as on other occasions, those most interested are willing to content themselves with arguing from the appearances of the passing moment, or from a set of rules which, almost without effort, they have formed for themselves. It is to be admitted that farmers, and a great number of others, are generally furnished with a barometer or weather-glass; but this instrument from its indications as to height not being combined with other circumstances is seldom of much use to them, and not unfrequently leads them into errors, which might have been avoided, under a more comprehensive consideration. Dr. Hally appears to have been the first who drew up, from an extensive series of observations, the laws which govern the motions of the barometer, and it is to his conclusions we shall here advert. He states the most general phenomena in eight propositions.

1. In calm settled weather, when the air is inclined to rain, the mercury is uncommonly low.

2. In serene, good, settled weather, the mercury is generally high.

3. Great winds, though not accompanied with rain, sink the mercury lowest of all, with relation to the point of the compass the wind blows upon.

4. The greatest heights of the mercury are observed during the easterly and north-easterly winds.

5. In calm, frosty weather, the mercury generally stands high.

6. After great storms of wind, when the mercury has been low, it generally rises again very fast.

7. The more distant places are from the equator, the greater the range of the mercury in the barometer.

8. Within and near the tropics, the variation of the mercury is very little in all weathers.

Hence he considers the principal cause of the rising and falling of the mercury to be variable winds which are found in the temperate zones, and which in England are remarkably inconstant. A second cause is the uncertain exhalation, and precipitation of the vapours lodging in the air, which is thereby rendered heavier or lighter; but this cause is in a great measure dependant upon the former; but it will now be necessary to state more minutely the particular states of the weather which are likely to follow such changes.

1. The rising of the mercury generally presages fair weather, as its falling does the contrary, or rain, snow, high winds and storms.

2. In very hot weather, the sudden falling of the mercury portends thunder.

3. In winter, the rising indicates frost; and in frosty weather, if the mercury falls three or four divisions, there will certainly follow a thaw; but if it rise in a continued frost, it will be accompanied with snow.

4. When foul weather quickly succeeds, after the falling of the mercury, it will not be of long duration; nor are we to expect a continuance of fair weather when it soon succeeds the rising of the mercury.

5. If, in foul weather, the mercury ascends considerably and continues in an advancing state for two or three days successively, before the foul weather is over, then we may expect fine weather of some continuance.

6. If, in clear weather, the mercury falls remarkably for two or three days together, before the rain sets in, it is highly probable that much rain, and perhaps high winds will follow.

7. An unsettled state of the mercury indicates changeable weather.

8. The mercury sometimes falls considerably without any remarkable change following it, this may arise from a distant storm, or even an earthquake.

9. If the mercury begin to rise steadily from a low state, and the wind change from the south or west, to the north or east, fine weather may be expected.

10. A rapid movement of the mercury, even when rising, is an indication of bad weather, though not of long continuance.

11. The rising of the barometer is a more certain indication of fair weather, than its sinking is of rainy weather; because it so often sinks for wind as well

as rain. If, therefore, while the barometer is sinking, the atmosphere still remain clear, wind may be expected.

With respect to prognostics of the weather independent of the barometer, and which indicate the general state of an approaching season, Kirwan has deduced the following rules from observations made in England during a period of one hundred and twelve years.

1. When no storm has either preceded or followed the vernal equinox, the succeeding summer is in general dry, or at least five times out of six.

2. If a storm happen from an easterly point, on the 19th, 20th, or 21st day of May, the following summer will four times in five, be also dry. The same event generally takes place, if a storm arise on the 25th, 26th, or 27th days of March, in any point of the compass.

3. Should there be a storm, either at south-west or at west-south-west, on the 19th, 20th, 21st, or 22nd of March, the following summer is wet five times out of six.

To these prognostics of the weather might be added many others; but, perhaps, the list has been already sufficiently extended. The work of observation, on all the changes of the atmosphere that can be detected by instruments, is now carrying on, to an extent without example in former times; and it is only as these come forward that prognostics of real value can be multiplied.

SOUND.

The only remaining mechanical property of air which we have to notice, is that which renders it the medium of *sound.*

Any body which produces sound by collision from another, is called a *sonorous* or *sounding* body; though the term sonorous is more especially applicable to such bodies as produce a distinct and continuous sound, like a bell, or the string of a musical instrument, than to those which produce a dull and momentary sound, like that of clashing together two pieces of chalk.

The velocity of sound, though the subject of different opinions, has been examined with considerable success, and on the authority of numerous experiments, it is supposed to travel uniformly at the rate of about 1,142 feet in a second, or one mile in rather less than five seconds. All sounds move with the same velocity; the gentlest whisper moves over the same distance to which it extends, as rapidly as the report of a cannon over the same distance. An orator, with a good voice, may easily make himself heard at the distance of one hundred feet in a direct line before him; but he will not be heard with equal distinctness at more than the distance of eighty feet on his right and left; or of forty feet immediately behind him.

A knowledge of the velocity of sound is obviously applicable in certain cases, to the purpose of determining distances. If a vessel is observed to fire a gun, and eight seconds elapse between seeing the flash and hearing the report, the distance of that vessel is 8 times, 1,142 feet, or 1 mile 1,185 yards; because the flash and the report in reality happen together, and the velocity of light is so great, that, at any terrestrial distance it may be considered instantaneous. In the same manner may be estimated the distance of thunder, by noticing the number of seconds that intervene between seeing the lightning and hearing the thunder.

When smooth and level ground is interposed between the sounding body and the hearer, the sound is heard at a much greater distance, than when houses, walls, trees, crops of grain, &c., are interspersed in the path of sound. Over the surface of smooth water, sound is conveyed admirably well, and may be heard at a greater distance than in any other way which nature affords. By placing the ear close to the ground, or to the water, distant sounds may be be heard which would otherwise be imperceptible. The inhabitants of uncivilized countries understand this practice.

The vivacity with which sounds are transmitted through solid substances is very remarkable. The scratch made with a pin at one end of a piece of timber, fifty feet long, may be distinctly heard by an ear placed close to the other end, although the same could not be heard through the air at the distance of a dozen feet.

When the air, in a state of vibration, strikes upon a solid regular surface, it is reflected by it in the same state, at an angle equal to the angle of incidence. An ear, therefore, situated in the direction of these reflected vibrations, perceives a sound similar to the original one, but apparently originating in a right line with its last direction, equal to the reflected and incident course. These reflected sounds are called *echoes;* they cannot on account of the great velocity of sound be distinguished from the original sounds within the space of fifty-five feet from the reflecting surface, therefore an echo must always be at that distance: when the reflecting surface is nearer, it is only said to increase the sound. As reflecting surfaces produce various differences, according to their distance, figure and composition, the effects of echoes are very different.

"It is in general known," says Goldsmith, "that caverns, grottos, mountains, and ruined buildings return this figure of sound. Image, we may call it; for in every respect it resembles the image of a visible object reflected from a polished surface. Our figures are often represented in a mirror without seeing them ourselves, while those standing on one side are alone sensible of the reflection. To be capable of seeing the reflected image of ourselves, we must be directly in a line with the image. Just so it is in an echo—we must stand in a line in which the sound is reflected, or the repetition will be lost to us, while it may, at the same time, be distinctly heard by others who stand at a short distance to the one side of us. I remember a very extraordinary echo, at a ruined fortress near Louvain, in Flanders. If a person sung, he only heard his own voice, without any repetition; on the contrary, those who stood at some distance, heard the echo, but not the voice; then they heard it with surprising variations, sometimes louder, sometimes softer, now more near, then more distant."

HYDROSTATICS AND HYDRAULICS.

The science of Hydrostatics treats of the pressure and equilibrium of fluids in general; but it is chiefly exemplified by the developement of the mechanical properties of water, excepting so far as this fluid is dependent for its effects upon its motion. The science which teaches the laws of fluid in motion, and the application of fluids in that state to machines is called *Hydraulics*. This distinction between Hydrostatics and Hydraulics, appears to make two sciences of subjects too intimately connected to be considered in any other light than as including only different parts of the same subject. We have, therefore, classed them together, and shall regard them as convenient heads for different chapters, on the properties common to fluids.

HYDROSTATICS.

A fluid is a body whose particles yield to the least effort of partial pressure. Fluids are of two kinds, *elastic* and *non-elastic*. Elastic fluids are those in a state of air and gas; their bulk varies with the force compressing them, and in their other mechanical properties they resemble common air; the general laws relative to them are, therefore, to be derived from pneumatics. Non-elastic fluids, as oil, water, spirit, or wine, are either absolutely or very nearly incompressible. These are the bodies with which hydrostatics are chiefly concerned.

The cause of fluidity has been the subject of much speculation, but one opinion is, that the particles of fluids are spherical, in consequence of which configuration they slide over and among each other with prodigious facility. This assumption cannot be affirmed by experiment, no microscope being powerful enough to show the component particles of any fluid, but it is favoured by the proofs we have of the numerous interstices of fluids. In water, for example, salt and various other bodies may be dissolved in considerable quantity, without enlarging its dimensions. According to this theory, also, the densities of different fluids are accounted for, by supposing their spherical particles to be of different sizes, the densest fluid having always the least particles; but why the particles of various solids should assume a spherical figure by the action of fire, which fuses them, and some other figure when these bodies become solid in cooling, is not so easily determined. It is, therefore, the opinion of others that fluidity is simply the consequence of the caloric (heat) combined with different bodies, the caloric surrounding these particles and lessening their cohesion so much that they slide very easily over each other. When, however, so much caloric is abstracted, that the attraction of cohesion can operate, fluids become solid. Perhaps this theory would be improved, if the former were combined with it, rather than wholly rejected. Caloric, it may be supposed, will most easily lessen the attraction of cohesion between particles perfectly spherical, because these have the fewest points of contact; bodies may, therefore, be more or less easily rendered fluid, in proportion as their particles differ more or less from the spherical figure.

Though the particles of fluids have certainly a very small degree of cohesion to each other, yet it is not so small but that it may in a variety of instances be rendered visible. For example, it is the attraction of cohesion that prevents a drop of water, placed gently on any dry surface, from extending itself; and that allows a vessel to be filled above its brim with water, which could not happen if water were a perfect fluid.

The academy of Florence inferred the total incompressibility of water; but Canton established some conclusions which showed that the inference drawn by the Florentines was not to be accepted without limitation. He found that water expended one part in 21,740, when the pressure of the atmosphere was removed, and submitted to a compression of one part in 10,870 under the weight of a double atmosphere. He also observed that water possessed a most remarkable property, of being more compressible in winter than in summer; contrary to the effect on spirits of wine and oil of olives. It remains, therefore, for future investigation to fix the judgment of philosophers on this subject; in the meantime, even granting all the compressibility that has been contended for, the quantity of it is too small to be noticed in practice.

Persons at sea frequently try an experiment which proves in a great degree the incompressibility of water. Having corked a bottle containing only air, and therefore called empty, they tie a rope to it, and sink it to a considerable depth by a sufficient weight; on pulling up the bottle, they generally find it either broken, or the cork forced in. But on sinking to the same, or any greater depth, a bottle filled with water, they find it, when drawn up, to be uninjured, because the water resists compression, and therefore supports the

the bottle; which support, under the pressure at a great depth, the air cannot supply.

Fluids, as well as solids, press downwards by gravitation, according to their quantities of matter, endeavouring always to attain the lowest place possible, or place nearest the centre of the earth; but they have this peculiarity, that they press in every direction alike, in proportion to their perpendicular height, and not their quantity. It is from this property of pressing in every direction, that the sides of vessels containing fluids, although at rest, must be made strong like the bottom; or if any difference be made, it must be gradual towards the top, because the pressure diminishes with the diminution of the column sustained.

The downward pressure of water may be proved, where wood and other bodies lighter than water refuse to swim. Take two pieces of wood, planed so perfectly flat, that when put together no water can get between them; cement one of them to the bottom of a jar, or any vessel capable of holding water; place the other piece upon the one so cemented down, the two flat faces, of course, being in contact. Press upon the upper piece with a stick, to prevent its moving while the vessel is filled with water;. after which, the stick being withdrawn, the loose piece of wood will remain in its situation, as steadidly as the piece cemented down, because it is pressed by all the weight of the water over it; but if it be raised, however little, at one edge, some water will then get under it, which being acted upon by the water above, will immediately press it upwards, and from its lightness it will reach the surface.

On the disposition of water to press upwards to the level of its source, depends the existence of springs, which always originate in higher situations than those in which they are found. Of this property they ancients appear not to have been aware. When they had water to convey from one hill to another, they were at the expense of constructing an immense aqueduct to cross the valley in a right line from the source, without reflecting how commodiously the same might be effected by a pipe.

From the pressure of water being as its perpendicular height, it becomes necessary to guard against its effects in the construction of canals and other reservoirs; for when a column of water insinuates itself under a bank, if its upward pressure exceed the resistance of the weight upon it, which might frequently happen, the bank will be destroyed. Such accidents are prevented by lining the bottoms of the reservoirs with clay, or some material impervious to water.

SPECIFIC GRAVITY.

The expression, specific gravity, is of very frequent occurrence in scientific works; the explanation of it, and the method of determining the specific gravity of any body, forms an important branch of hydrostatics.

The specific gravity of a body is simply the expression of its weight, when compared with an equal bulk of distilled water. For example, the specific gravity of gold is to the specific gravity of water as 19 to 1; the meaning of which is, that a given magnitude of gold, for example, a cubic inch, will weigh nineteen times as much as the water that could be contained in a vessel, the capacity of which is precisely equal to one cubic inch.

When a solid body is wholly immersed in a fluid, or as the fluid presses upon and touches it at every point, it is evident that the quantity of fluid displaced must be precisely equal to the bulk of the body immersed in it: consequently it follows, that the greater the density of the body,—that is, the greater its weight for its bulk,—the less will be the quantity of fluid which any given weight of can displace, When a body sinks in a fluid of its own accord, it is because of its being heavier than an equal bulk of that fluid, in consequence of which it overcomes the upward pressure by which it is opposed; this upward pressure, supposing the fluid to be water, is equal only to its bulk of that fluid, and, therefore, after deducting the weight of its bulk of water, the remainder is the force with which it sinks. Thus, if the weight of a body be three ounces, and the weight of its bulk of water be one ounce, it will sink in water with a weight of two ounces. This accounts for the different degrees of rapidity with which different bodies sink.

From the above remark, that the force with which a body sinks in water is less than what it weighs in the open air, by the bulk of the water it displaces, this hydrostatic axiom is plainly deducible, that every body immersed in water, and every other fluid, loses just so much of its weight as equals the weight of an equal bulk of the water or other fluid. A knowledge of this truth renders the most admirable assistance in detecting the identity of substances, when all other characteristics, that can be conveniently resorted to, prove ineffectual; of this a remarkable example and illustration immediately resulted from its first discovery, which happened in the following manner:—

Hiero, King of Syracuse, had employed an artist to make him a regal crown of gold, and had furnished a sufficient quantity of pure metal for that purpose. When the crown was brought home, its weight was found to be equal to that of the gold delivered for it, yet the king suspected an adulteration. He applied to the celebrated Archimides for the means of detecting the amount of the fraud; the philosopher could not for some time arrive at any satisfactory conclusion, but at length an accidental observation which he made, reminded him of the means he might employ. When stepping one day into a bath, he took notice that the water rose in proportion to the quantity of his body immersed in it, and immediately reflecting that a body of equal bulk with himself would raise the water in the same degree, though a body of equal weight, though not of equal bulk, would not raise it so much, he became instantly alive to all the consequences of this reasoning, and in the ecstacy of the moment, without recollecting his clothes, he ran into the streets of Syracuse, exclaiming—"I have found it! I have found it!" He forthwith took masses of metal, each of them equal in weight to the crown, but one of them was of pure gold, the other of silver. These he separately let down into a vessel containing water, the rising of which by the alternate immersion of the masses, could easily be determined by measure. He found that the silver displaced a greater body of water than its weight of gold; he then tried the crown, and found that it displaced more water than its weight of gold, but not so much as its weight of silver. By these means he discovered that the crown was not made of pure gold, and by comparing his observations on the bulk of water displaced by the crown, the gold, and the silver, he discovered the quantity of gold the crown actually contained.

As whatever weight a body is found to lose, on being weighed while suspended in water, is the same as a quantity of water equal to its bulk; hence to obtain specific gravities, it is not necessary to reduce solids to any given size, in order to compare them by measurement, but they are taken of any size or figure, and first weighed in air, and then in water, by means of a hydrostatic balance.

THE DIVING BELL.

The nature of the diving-bell may be easily understood by reflecting on the facility with which air may be retained under water, in vessels open only at the bottom, because, like any solid, it prevents other bodies from occupying the place it occupies itself.

Thus if we take a glass tumbler, or any similar vessel, and hold it inverted, push it vertically downwards into the water, the air it contains will not escape, and the water at inconsiderable depths, will scarcely rise at all within it. It is clear, that whatever were the size of the vessel, the water would in the same manner be excluded by the air, and as the air is the same as that of the atmosphere, it is equally clear, that in a vessel of sufficient size, men might be stationed without being incommoded by the water, as they could breathe the air, and live till its vital principle was exhausted. If then any means were contrived to remove the contaminated air, and to send down a fresh supply of fresh air, they might remain under water any length of time that they chose, and if let down by a rope to a wreck, or to the bottom of the sea, they might perform any work of which the size of the vessel admitted, or to which they were competent on the land. The vessel used for this purpose is called a bell, because it is much in the form of a truncated cone, and often resembles a bell in its general appearance. It must be mentioned, however, that the water, in proportion to the depth to which the bell is sunk, rises within it, by the increase of its pressure, and compresses the air. At the depth of thirty-three feet under water, the water presses into the bell with the power of a double atmosphere, and the air, which, when it was at or very near the top, occupied the whole interior capacity, does not then occupy more than half of it, consequently the bell becomes half full of water; and at all greater depths the air sustains a proportionably greater compression, the water at the same time rising as this effect goes on, till at length it covers the divers.

Dr. Halley was the first person who materially improved the diving-bell. He formed a machine of this kind of copper in the form a bell; and weights of lead were distributed about the lower part, to keep it in an inverted position, while they rendered it at the same time specifically heavier than its bulk of water, and consequently it would sink by its own weight. It was three feet wide at the top, five feet at the bottom, and eight feet high. In the top, was a window of very thick glass and also a stop-cock, to let out the hot air which had been breathed; and within the bell was a circular seat for the drivers. To supply the divers with air, two barrels of about sixty-three gallons each, cased with a sufficient quantity of lead to make them sink, were prepared to be sent down to the divers. The bung-hole in each barrel was left open, and kept on the under side, to let in the water as the air in the barrels condensed during their descent, and to let the water out again when they were drawn up. To a hole in the upper side of the barrels, was fixed a leathern pipe, well prepared with bees' wax and oil, which was long enough to fall below the bung-hole at the bottom, and kept down by a weight in such a way that the air in the upper-part of the barrels could not escape, unless the lower end of these pipes were first lifted up. These air barrels, by means of proper tackle, were made to rise and fall in succession, like two buckets in a well; in their descent they were directed to the divers by ropes fastened to the under edge of the bell, and one person held himself always in readiness to receive them, and by taking up the end of the pipes above the surface of the water in the bell, the water by its pressure filled the barrels, while the air they contained rushed into the upper part of the bell. As soon as one barrel was discharged, by a signal given it was drawn up, and another sent down; thus a continual supply of fresh air was supplied to the divers. Mean-while, as the cold air rushed into the bell from the barrel, it expelled the hot air at the top where the stop-cock was opened for that purpose. Dr. Halley was himself one of five, who went down together in his bell;

they remained at the bottom, at the depth of ten fathoms, for an hour and a half without experiencing any ill effects, and might have continued any length of time that they chose. The window in the top of the bell let in so much light, that when the sun shone, and the sea was unruffled, they could read and write with great ease, and could see the pebbles or take up any small objects that happened to be at the bottom; but every thing they saw appeared red. By writing with pieces of sharpened iron upon small pieces of lead, which they sent up with the returning air barrel, they maintained a communication with those above, and directed the bell to be moved as they desired. In misty weather, and when the sea was rough, it was nearly dark in the bell, and it became necessary to burn a candle, which consumed as much air as one person. The divers in descending with this bell, felt a pain in their ears; as if the end of a quill had been thrust into them. The sensation was owing to the pressure of the condensed air upon the tympanum; it went off gradually as the air in their bodies became as dense as that without. It appears by this account, that the pressure of a double or even threefold atmosphere is much more endurable than the diminution of the ordinary pressure to half a single atmosphere.

The main rope by which a diving-bell is supported, ought to be soaked in water before it is used; or it would perhaps be still better if a chair were substituted. An instance occurred in the bay of Dublin, where the rope, in suffering the contraction which water always occasions, caused a diving-bell to turn round. by which means the signal strings were entangled. The people above, not receiving the expected signals, drew up the bell; but they were too late; the two men it contained were both dead; not drowned, but suffocated by the want of a supply of fresh air.

Another circumstance proper to be attended to, in using a diving-bell, is to lower it very gradually through the water, to prevent the injurious effects which the abrupt condensation of the air contained in it might have upon the men.

HYDRAULICS.

We will now consider the objects of hydraulics, which relate to the laws and uses of fluids in motion. Here, as in hydrostatics, though the doctrine laid down might be applied to fluids in general, allowing for differences in density, yet water is the fluid constantly referred to; because it is the fluid with which men are most extensively concerned, and elucidations specifically applied give greater precision to the subject.

MOTION OF WATER FLOWING OUT OF RESERVOIRS.

When a vessel, containing water, and open at the top, is pierced below the surface of the fluid, the velocity with which the water flows out is observed to be greatest at first, and to diminish gradually as the water sinks, and the nearer the aperture is to the bottom, the greater the quantity which flows out in a given time. From a hole on the level with the bottom of the vessel, the water would emerge with nearly the same velocity as if it were in the bottom. This egress of fluids from the perforated sides of vessels, is a consequence and a proof of their pressing in every direction: and the law, which governs the rate of it, is an admirable illustration of the harmony which distinguishes the operations of nature, although our limited powers are but occasionally competent to its developement: the velocity with which water flows out of an aperture at the side or bottom of a vessel, is as the square root of the distance of the aperture from the surface of the water. This is but saying in other words, that the velocity is according to the pressure or force which occasions it, and it has already been demonstrated that the pressures of fluids is as their perpendicular heights. In order therefore that double the quantity of water may flow through one hole that flows through another of the same size, the former must be four times as far from the surface as the latter; and if a supply of three times the quantity of water be required, without changing the size of the aperture; three times the velocity must be produced, and three times the velocity will require nine times the pressure; consequently the hole must be nine times as far from the surface of the fluid, as that which only produced a third of the supply. An experiment in proof of these positions is easily made: let two equal pipes be fixed into the side of a vessel containing water, but one of them at four times the distance from the other from the surface: let the pipes be allowed to run at the same moment, while water is constantly poured into the vessel, and kept at the same height in it during the experiment. Then if a cup that holds a pint be so placed as to receive the water that spouts from the upper pipe; and at the same time, a cup that contains a quart, be placed to receive the water from the lower pipe, both cups will become full at the same moment.

The horizontal distance to which a fluid will spout from an aperture, in any part of the side of an upright vessel, below the surface of the fluid, is equal to twice the length of a perpendicular to the side of the vessel, drawn from the mouth of the pipe to a semi-circle described upon the altitude of the fluid; and therefore, the distance will be the greatest possible when the mouth of the pipe is at the centre of the semi-circle; because a perpendicular to its diameter (supposed parrallel to the side of the vessel) drawn from that point, is the longest that can possibly be drawn from any part of the diameter to the circumference of the semi-circle.

The progress of water through a pipe is greatly retarded by every deviation from a straight direction, and by every enlargement, contraction, projection, or roughness it meets with in its passage; and most of these irregularities are of too variable a nature to be submitted to regular calculation. They operate in occasioning eddies or contrary currents, in counteracting which part of the moving force is inevitably lost. To avoid as much as possible the retardation from flexure, when it is necessary to give a new direction to a pipe, the point of flexure should not be sharp, but take as comprehensive a sweep as can be allowed.

MOTION OF WATER IN RIVERS, AND WAVES.

THE motion of a river is in general produced by gravitation, which obliges the water to descend from a higher to a lower situation; and therefore it is swift or slow according as the descent or inclination of the bed of the river is great or small. Sometimes, or in some parts of rivers, the motion is produced by pressure, or disposition of the water to spread itself out, in which case it increases with the depth.

To ascertain whether the water of a river, almost horizontal, flows by means of the velocity acquired in its descent, or by the pressure of its depth, set up a stake perpendicularly in it, then if the water rise and swell immediately against the stake, it is the descent which occasions its motion; but if it first stop a little, it is impelled by pressure.

A very simple mode of ascertaining the mean velocity of a stream, consists in the use of a pole of light wood, about the same length as the depth of the stream: the lower end of this pole is loaded, so that in the water it will remain in a vertical position, with its upper end near the surface; the preparation is finished by fixing in the upper end, exactly in the direction of its axis, a slender rod to project above the water. This pole being placed in a river, the rod will point up or down according as the stream is swiftest at the surface or near the bed; and the rate of its motion, in any given space of time, will be the mean velocity of that place.

The waves formed on water by the action of the wind, are superficial oscillations of the wind that are by no means so irregular in their action as might be inferred. The first impression of the wind upon the water is to produce a cavity; this cavity cannot be produced without heaping up the water before it; the water thus heaped, having attained an elevation proportionate to the force which caused the depression, sinks down towards its level, but in thus sinking down, it acquires a velocity which carries it below its level; by this means it produces a depression like that caused by the wind in the first instance, and thus successive waves are propagated, but the motion diminishes in proportion to the distance over which the force extends.

The depth to which the sea is agitated, even in violent tempests, is not very considerable; at the depth of twenty feet below what is the level in a calm, the effect is very slight, and at thirty feet it would probably be altogether imperceptible. It may therefore seem difficult to account for the mountainous waves encountered by seamen; but it must be remembered that the wind is constantly acting, and that one wave is raised on the top of another, till the accumulation becomes prodigious.

When a stone or any other body is thrown into a vessel containing oil, it agitates the surface nearly as much as if thrown into a like quantity of water; but the power of the wind on a surface of oil is exceedingly small, and incapable of producing more than a slight undulation. A quantity of oil in the proportion of an ounce to an acre poured out on the windward side of a lake, will spread itself over the whole surface, and stilll the waves raised by the wind.

HYDRAULIC MACHINES.

THERE are many machines for hydraulic purposes which the limits of this volume will prevent us from giving little more than their names and uses; but this is the less to be regretted as they are in general so well known that a short notice of them here will suffice.

The common pump with which water is drawn out of wells is usually called a *Sucking-Pump.* This appellative originated at a period when the effect was attributed to suction, and ought to have been rejected when the pressure of the atmosphere was proved to be the efficient agent in causing the water to rise.

The velocity of the stroke of a pump should never be less than four inches, nor greater than two or three feet in a second; the stroke should be as long as possible, to prevent loss of water by the frequent alternations of the valves. The diameter of the suction-pipe is best proportioned, when it is from two-thirds to three-fourths of that of the barrel.

The *Lifting Pump* is generally used for great water-works, and where the water is not to be brought up from any great depth. It is variously constructed, but in general the upper valve is fixed, and the lower one moveable; and the water is, in fact, lifted, as if it were in a bucket; the sides of the bucket being formed by the barrel, and the piston forming its bottom.

The *Forcing Pump* is furnished with two valves, which are both stationary, or open and shut in the same situation. A forcing pump is the essential part of an engine for extinguishing fires. These engines have generally two forcing pumps, and the pipe for the air vessel, except at the extremity, is made of leather, or some pliable material, that the jet may be easily directed to any given point.

The *Screw of Archimides.*—This useful invention originated with the famous Archimides of Syracuse. It is formed by wrapping a tube around a cylinder, in the form of the thread of a screw. The cylinder is suspended upon pivots, and turned by means of a winch; its position is inclined to the horizon, with its lower end in the water to be raised. The tube or spiral is open at both ends, and when, by turning the winch, the lower orifice strikes the water, the water gradually rises in the tube till it is at last discharged at the upper orifice. When the water is raised out of a river by means of this screw, if a wheel with floatboards be attached, the screw will be wrought by the stream itself.

This screw has been successfully used to propel steam-boats, in place of the paddle-wheels.

The *Rope Pump.*—If a pulley, set in motion by a large wheel, is fixed in a suitable frame over the mouth of a well, while another pulley is situated in a similar situation in the water of the well, and an endless rope passes over both pulleys; on revolving the large wheel, every part of the rope will successively dip into the well, and after attaining the top of the upper pulley, will, in descending, throw off, by its centrifugal force, a portion of the water it has imbibed, the quantity of which, when the rotation is quick, will be very considerable.

The *Hydraulic Press.*—This is a very useful invention for those who require great pressure, such as packers, printers, &c. It occupies very little space, and may be made several hundred tons pressure, which can be applied at any time by a boy.

The *Steam Engine.*—The first person who entertained the idea of employing steam as a motive force, is not certainly known; but the earliest application of steam to this object, is not carried further back than the year 1629, when an Italian, called Brancas, published an account of an invention of his, in which steam ejected from a large æolipile was the force that wrought a stamping engine. Thirty-four years afterwards, in 1663, the Marquis of Worcester, a nobleman of great ingenuity, published a little work, called "A Century of Inventions," in which one hundred contrivances of his own were enumerated; the account he furnishes of each is short, and often very obscure; with the latter fault is particularly chargeable in the description he furnishes of an engine for raising water by the force of steam. At this day we have no means of certainly knowing whether the discovery of Brancas was known to the Marquis or not; but it is not suspected that he was acquainted with it, and therefore the English are inclined to consider the original idea of the steam-engine as having arisen in their own country: the French, on the contrary, claim it for themselves, and bring forward the name of Papin; but Papin's application of steam as a motive force was not published till 1690, which was twenty-seven years after the Marquis of Worcester's publication. But let it even be supposed, that for Brancas, the Marquis, and Papin, the claim to independent and original invention could be substantiated, yet the Italians and the French have no claim to notice afterwards for following up the ideas of their countrymen; it is solely to the English that the world is indebted for rendering the steam-engine what it now is, the noblest machinery ever invented by man; the pride of the machinest,—the admiration of the philosopher. Animals require long and frequent periods of relaxation from fatigue; and any great accumulation of their power is not obtained without great expense and inconvenience; the wind is changeable to a proverb; and water, the constancy of which is in few places equal to the wants of the machinist, cannot in general be obtained on the spot where other circumstances require machinery to be erected. To relieve us from all these difficulties, the last century has given us the steam-engine for a resource; the power of this assistant may be accumulated indefinitely; it requires but little room; it may be erected in all places; and its mighty services are always at our command; whether in winter or in summer, by day or by night, it knows of no intermission but what our wishes dictate. But we must forbear as we could fill a volnme on this subject.

MAGNETISM.

A PECULIAR species of attraction, exerted by bodies called magnets or loadstones, receives the appellation of *magnetism.*

Of magnets there are two kinds, viz., the natural and the artificial. The natural magnet is a mineral, so hard as to strike fire with steel; its colour is dull, and generally either dark grey, or brown, or nearly black. It is an ore of iron, and derives its name of magnet from its possessing the singular property of attracting ferruginous substances, with a force entirely independent of the ordinary properties of matter.—This power of attraction may be communicated to iron in any state, under a variety of circumstances; and iron imbued with it in any considerable degree, is called an *artificial magnet* or *loadstone.* Magnetism is an accidental property of iron, which may either possess or be deprived of it without losing any of its essential characteristics.

Magnetic attraction was till lately supposed to be exerted by ferruginous bodies alone on other ferruginous bodies, and hence the use of the magnet was resorted to, with a view to detect the presence of iron; but modern investigations render it probable that nikel is also susceptible of it. Richter, having made a series of experiments on this metal, considers it more attractable by the loadstone than iron; and Chenwix is of opinion that both nikel and cobalt are really magnetic; and that, when this does not appear to be the case, it is owing to their combination with arsenic.

A magnet, suspended by a thread, or placed in any situation that leaves it at liberty to move with freedom, turns one part of its surface towards the north pole of the earth, and, consequently, the opposite part of its surface towards the south pole. Those parts of the surface of a magnet which assume the position stated, are called its *poles;* they are not reversible points, but the pole which is at any time observed to point towards the north, always points in the same direction, or nearly so, and the like remark must, of course, apply to the other, or south pole.

The attractive properties of the magnet have been known from time immemorial; but it was not till about the close of the twelfth, or beginning of the thirteenth century, that its directive property became known. The discovery of it is generally attributed to John de Gioja, a handicraft of Naples, although several authors, previous to his time, had obscurely hinted their knowledge of it. Gioja, having observed the property by accident in a few magnets, soon extended his researches, and found that it was common to them all, at least at the place where he lived. Sensible of the value of the acquisition the world would obtain if the property he had thus discovered remained unimpaired by time or place, he made several journeys to various parts of Italy, to prove its immutability, and his inquiries satisfied him that there was no perceptible difference in it, except by the vicinity of masses of iron. The first trial of the directive power of the magnet on the water consisted in mooring a vessel out at sea, in a direction corresponding with that of the magnet; and a boat, having a magnet suspended by its centre on a pivot, was despatched at night in the exact line the magnet pointed out, the consequence of which was, that it arrived at the place where the vessel was at anchor. Such was the origin of the mariner's compass, the inestimable value of which as a guide in crossing the ocean, and trackless deserts, as well as in other circumstances of minor importance, can be more duly appreciated by the supposition of our situation under the want of it, than by any other means.

The magnetic needle does not, in general, rest exactly in the direction of the meridian of the place where it is observed, consequently not directly north and south. This phenomenon, which is called the *Declination of the Magnet*, was discovered in the year 1500; but the son of Columbus asserts, that his father observed it in 1492. At first it was not doubted, that the magnetic declination was an equal quantity at all times and places; but Gellibrand, an Englishman, discovered that it was variable, and published an account of this discovery in a pamphlet printed in 1635.

Another property of the magnetic needle, much more singular than that of the declination is, that when suspended by the point which would be its centre of gravity according to its mass of matter, it does not remain horizontal, but one extremity sinks lower than the other. This is called the *dipping* of the needle or magnet, and it varies in different latitudes. In the southern hemisphere, it is the south pole which is depressed; and in the northern hemisphere it is the north pole. At the equator, the needle assumes a position almost correctly horizontal. The dipping of the needle was discovered by R. Norman, who published his account of it in 1581, but he had ascertained the fact a considerable time previously.

If the north pole of one magnet be presented to the south pole of another, the two magnets will attract each other; but if the north pole of one be presented to the north pole of the other, they will repel each other, provided they be suspended by thread, or in any way at liberty to move with perfect freedom. This is called *Magnetic Repulsion.*

Magnetic repulsion never takes place except between poles of the same name; thus a north pole repels a north pole; and a south pole repels a south pole; yet, when the north pole of a weak magnet is presented to the north pole of a powerful one, an attraction is often observed; but when this occurs, it is found that the poles of the weaker magnet have been in reality reversed, and its north pole has acquired polarity.

THEORY OF MAGNETISM.

THE only proposition towards the Theory of Magnetism, which seems placed beyond the reach of doubt, is, that the earth itself acts as a great magnet; and if this be evident, it will scarcely be denied, that all other magnets derive their properties and power from its effects. Supposing the earth to be a magnet, the manner in which it operates, in causing the directive property and inclination, or dipping of the needle, is just what might be expected, and may be exemplified by an easy experiment: over the needle of a magnet, hold a magnetised needle, suspended by a fine thread, and so fixed, that if it were removed to a distance from any magnet or iron, it would remain horizontal. In this position, the needle, being equally attracted by both ends of the magnet, remains horizontal, but it turns its north pole to the south pole of the magnet, and its south pole to the north pole of the magnet. A globular magnet exhibits this epitome of magnetism in a still more agreeable manner, and a magnet of that kind, made for the purpose, is called a terella, or little earth. As the large magnet, in this experiment, acts upon the needle, so does the earth upon all other magnets. When the centre of the needle, in this experiment, is over the centre of the magnet, it corresponds nearly to the situation of any suspended magnet at the equator of the earth, where the attraction from both poles is nearly equal; and where the needle would be exactly horizontal, if the magnetical and geographical poles of the earth coincided; but as this is not the case, the magnetical and geographical equators are differently situated.

That the earth is a magnet also admits of strong collateral proofs; it may be inferred from the vast quantities of ferruginous bodies contained in it, which are often dug up in a magnetical state, and from the magnetism which iron acquires by its position. Yet all this carries us but a very little way towards a complete theory of magnetism. For example, it is found, that the magnetical poles of the earth change their situation, and this singular circumstance has opened a wide field for speculation. It has been supposed that the earth contains a detached internal magnet, which has a different motion from that of the earth, though both their axes coincide. This internal loadstone is supposed to be separated from the outer globe or earth by a fluid medium; and to account for the variation of the needle westward, they suppose its motion with respect to that of the earth, to be such, that its north pole revolves from east to west, at the rate of one degree in five years, so as to make a complete revolution in 1920 years. This theory has never given much satisfaction; and it seems much more rational to conclude, that the magnetism of the earth arises from the magnetism of all the magnetic substances it contains whether intermixed with other bodies or not; that the magnetic poles of the earth may be considered as the centres of the polarities of all the particular aggregates of the magnetic substances within the earth, are by various causes altered, so as to have their power diminished, increased, approach to, or removal from the principal poles. The agents adequate to the production of these effects may be, heat and cold, volcanoes, earthquakes, electricity, chemical decompositions, and probably several others, of which philosophers have no knowledge.

By those who had so far deserted the paths of morality, as greedily to fatten upon the weaknesses of their fellow creatures, and boldly to venture upon any practice, however really flagitious, if it promised gain, and was screened from legal punishment; a pretended art, called animal magnetism, was impudently announced as curative of all diseases incident to the human body. The vulgar, who are always perversely fond of a mysterious creed, seized the bait, and the pockets of the projectors overflowed with the receipts of their impositions. When the folly of the moment had passed away, and the subject was rationally examined, abundant evidence was furnished, that though the human body contained, like most other substances, a small quantity of iron, the action of magnetism produced no physical change upon it, and that, therefore, the cures said to have been performed by magnetic sympathy, were either absolute falsehoods, or mere efforts of a deluded imagination. After animal magnetism appeared to have had its day, and was sinking fast into disrepute, it was succeeded by a kindred invention, the wonders of which were performed by rods of metal called *metallic tractors;* but these quickly followed their parent to the grave.

MAGNETICAL INSTRUMENTS.

THE *Mariner's Compass.*—The chief magnetical instrument is the mariner's compass, which consists of a circular brass box, containing a card or paper divided into thirty-two points, at each of which is given the name of a particular wind, or name of the direction to which it points. Over the centre of this card is suspended an artificial magnet, which, from the smallness of its size, is called a needle. As the needle, allowing for its declination, always turns its north pole to the north, the helmsman can either keep the stem of the vessel always in the same direction, in which case he will always sail due north, or he can keep it in a direction any number of degrees distant from the north at his pleasure, by which means the compass becomes a universal guide.

In steering a vessel, it has been usual for the helmsman to have one compass, and the captain in his cabin to have another, and the want of a perfect correspondence between the instruments, or the inattention of one party, often rendered the helmsman chargeable with neglect, which he refused to acknowledge. To remedy such inconveniences, an improvement on the compass was made, by which the instrument used by the helmsman could at all times be seen from the cabin.

The *Azimuth Compass.*—This instrument is nearly the same as the preceding: the principal difference consists in its being adapted to two sights, through which the sun or a star may be seen, to find its azimuth, and thence to ascertain the declination of the needle at the place of observation.

The *Dipping Needle.*—To form this instrument, an axis is passed through a needle, of the same shape as the compass needle; the terminations of the axis are conical, and they fit into small holes, of the same shape, in two cross bars. The needle before it is magnetised, must be made so as to lie perfectly horizontal when suspended between those bars; then after being rendered magnetic, its north pole will be found in this country to dip about seventy-two degrees below its former situation, or level of the horizon. In a lower latitude the dip will not be so great; in a higher latitude it will be greater; and at the magnetic pole, which cannot be far removed from the pole of the earth, it would doubtless be vertical.

MAGNETICAL EXPERIMENTS.

1. If a small magnet be placed upon a table strewn with iron filings, and a tremulous motion be given to the table by a few blows, the filings will be observed to arrange themselves in a very curious manner. From the centre of each hand or pole of the magnet, they will lie nearly in a straight line; but on each side of the magnet they will dispose themselves in concentric curves, both extremities of which terminate in the sides of the magnet, and they have pretty nearly the magnetic centre for their middle point. The cause of this appearance is, that each particle of iron becomes, for the moment, a magnet, and disposes itself accordingly at the place where it lies; attracting, at the same time, the opposite poles of the neighbouring particles.

2. If a straight piece of wire which has been rendered magnetical, be twisted in a spiral form, its magnetism will be strangely confused: in some parts it will attract, in others repel the same pole; and this will, in some portions of the wire, take place on its opposite sides. This experiment appears to indicate the disposition of the fluid to flow in a right line.

3. A tee-totum with a piece of iron at the top of it may, even while in motion, be taken up by a magnet, and its motion, while thus suspended vertically, will continue as if it remained upon the table. The experiment may be rendered still more diverting, by taking up another tee-totum by the bottom of the first, and this second may have its motion in a completely opposite direction to the other.

ELECTRO-MAGNETISM.

The analogies that exist between the phenomena of magnetism and those of electricity, in their general character, in the laws which govern them, and in the various combinations they present, are so extensive and so remarkable, as naturally to suggest the notion that the agencies themselves from which they proceed must be allied to one another by some close and intimate relation. Adventurous theorists have advanced the doctrine that each of these principles is merely a modification of the other, and that both may be regarded as ultimately identical in their nature, constituting instead of two separate and primary powers a single power of a higher order of simplicity.

The connexion between magnetism and electricity was a favourite subject of speculation and inquiry among philosophers in the middle of the last century. Many were the efforts made to resolve this seductive problem, which continued, however, to baffle the labours of each succeeding experimentalist, who multiplied his attempts, and varied his processes, without approaching nearer to the point he aimed at; and also to elude the reasonings of those who theorized upon every new fact until they bewildered both themselves and their readers in the mazes of visionary and conflicting hypotheses.

In the year 1784, the following question was proposed by the Electoral Academy of Bavaria as the subject of a prize dissertation.—"Is there a real and physical analogy between electric and magnetic forces; and, if such analogy exist, in what manner do these forces act upon the animal body?" The essays received by the Academy on that occasion, were collected and published ten years afterwards, by Professor Van Swinden, of Franeker, the author of one of the essays for which the prize was awarded. The conclusion at which he arrived, after a long and elaborate discussion of the subject, was that the similarity between electricity and magnetism amounts merely to an apparent resemblance, and does not constitute a true physical analogy; whence he infers, that these two powers are essentially different and distinct from one another. The opposite opinion, the other hand, was maintained by Professors Steiglehmer and Hubner, who contended that so close an analogy as that exhibited by these two classes of phenomena, indicated the effects of a single agent, varied only in consequence of a diversity of circumstances. So many new facts have been brought to light since the time in which these authors wrote, that the reasonings adduced on either side in this controversy have now lost their interest, excepting that it is still curious to observe by what devious paths they were led away from the truth, at the moment when they had nearly reached it, and when a very slight variation in the form of the experiments would at once have disclosed it to their view.

Subsequent discoveries relating to the laws of electric and magnetic action both as respects attraction and repulsion, and also induction, have tended to confirm the analogy between them, and to corroborate the opinion that they ultimately emanate from a common source. Electricity, it is true, affects every species of matter with which we are acquainted, in nearly an equal degree; while magnetism, although perhaps equally universal in its operation, yet acts very feebly, and, probably, unequally upon most kinds of matter, and certainly exerts its principal energy upon iron, a circumstance which has to this day remained inexplicable; although we have acquired the knowledge that electricity, under certain modifications, will produce every effect of magnetism. Electricity, we know, may be transferred from one body to another; but magnetism can be excited by induction only, and is incapable of any similar kind of of transference. Still, however, there existed many positive facts, which, independently of all analagy, demonstrated that the magnetic needle was occasionally influenced in its movements by the action of electricity; and that, in certain cases, the magnetic properties could be excited by electric explosions. The appearance of the aurora borealis, which has all the characters of an electric phenomenon, has been very frequently observed to be accompanied by a disturbance in the position of the compass; and a delicately suspended magnetic needle has generally exhibited on these occasions, very frequent oscillations. Lightning, which is still more decidedly electric has been known in numberless instances, to destroy, and sometimes to reverse the polarity of the compass-needle; and many disastrous accidents happening to ships, in consequence of their mistaking their course, may very probably have been owing to this cause. In confirmation of this, we meet with a narrative recorded in the Philsophical Transactions, in which the ship Alexander, being one hundred leagues from Cape Cod, in latitude 48 degrees, encountered a violent thunder-storm; the mast was struck by lightning, which also reversed the poles of all the compasses in the ship, a change which was not discovered till the ensuing night, when the stars appeared, and it was found that they had been steering in the opposite course to that which they intended. It is also stated, that in one of the compasses, the end which had before pointed to the north now pointed to the west. Another instance is recorded in the same work, where a stroke of lightning passed through a box containing a great number of knives and forks, melting some, and scattering the rest about the room. It was found that all those which were not melted had been rendered strongly magnetic, so as to take up large nails, and other pieces of iron placed near them.

Experiments were tried with the electric battery, in imitation of these effects, and in order to ascertain the circumstances on which they depended. But although steel bars were easily rendered magnetic by passing strong electric shocks through them, yet the results were by no means uniform, and no general law could be traced as governing the production and distribution of the polarity thus induced. A large proportion of the effects appeared to be referable to the concussion which the particles of the bar received in consequence of the violence with which the accumulated torrent of electricity rushed through them, thereby giving efficacy to the inductive influence of the earth. The experiments of Mr. Scoresby, as reported in the Transactions of the Royal Society of Edinburgh, made with a view of determining the amount of this influence when aided by electric concussion fully confirmed the principle upon which that mode of explaining the phenomenon rests, by showing that the action of a powerful electric shock is, in a great measure, similar to that of a blow from a hammer, or to the forcible twisting of the iron, or any kind of mechanical violence.

Nothing illustrates more forcibly the proneness of the human mind to draw general conclusions from insufficient data, than the various opinions so confidently maintained by different experimentalists on this subject.

As nothing had been gained by following the more violent operations of highly-condensed charges of electricity, other philosophers occupied themselves in the attentive study of the more tranquil influence of this agent, when merely accumulated in insulated conductors, and exerting simply its attractive and repulsive powers in conjunction with those of magnetism. But however the actions might be combined, nothing could be detected that indicated any interference of agency or modification of effect consequent on the combination. An electrified body is found to exert the same attractions and repulsions on a magnetised needle, as it does on the same needle when devoid of magnetism; nor does it, like magnetism, exhibit any decided preference for iron compared with its action

on other metals. When the two agencies are u
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men in every part of Europe, and many year
before Voltaic electricity was applied with an
to determine the influence which it so direc
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magnetic properties. These experiments suggested to Ritter some vague idea that electrical combinations, when not exhibiting their electric tension, were in a magnetic state; and that there existed a kind of electro-magnetic meridian, depending on the electricity of the earth, at right angles to the magnetic poles. But these speculations were of too crude a nature to throw any distinct light on the true connection between magnetism and electricity.

The real discoverer of the magnetic properties of electric currents was M. Oersted, Professor of Natural Philosophy, and Secretary of the Royal Society of Copenhagen. In a work which he published about the year 1813, on the identity of chemical and electrical forces, he had thrown out conjectures concerning the relations subsisting between the electric, galvanic, and magnetic fluids, which he conceived might differ from one another only in their respective degrees of tension. If galvanism, he argued, be merely a latent form of electricity, so magnetism may possibly be nothing more than electricity in a still more latent form; and he therefore proposed it as a subject, worthy of enquiry, whether electricity, employed in this, its most latent form, might not be found to have a sensible effect upon a magnet. It is difficult clearly to understand what he means by the expression of *latent form*, as applied to electricity, but it is sufficient for us to know that in the various endeavours he subsequently made to verify his conjectures, he was led to such forms of experiment as afforded decisive indications of the influence of Voltaic currents on the magnetised needle. Yet even after he had succeeded thus far, it was a matter of real difficulty to determine the real direction of this action, and it was not till six years afterwards that his perseverance was at length rewarded by complete success.

The first account of his discovery that appeared in England, is contained in a paper which he himself communicated, in Thompson's Annals of Philosophy, for October, 1820; and in which the two following experiments are described:—The two poles of a powerful Voltaic battery were connected by a metallic wire so as to complete the galvanic circuit. The wire which performs this office is called the *uniting wire;* and the effect, whatever it may be which takes place in this conductor, and in the space surrounding it, during the passage of the electricity, he designates by the term *electric conflict*, from an idea that there takes place some continued collision and neutralisation of the two species of electric fluids, while circulating in opposite currents in the apparatus. Then taking a magnetic needle properly balanced on its point, as in the mariner's compass, and allowing it to assume its natural position in the magnetic meridian, he placed a straight portion of the uniting wire horizontally above the needle, and in a direction parallel to it; and then completed the circuit, so that the electric current passed through the wire. The moment this was done the needle changed its position, its end deviating from the north and south towards the east and west, according to the direction in which the electric current flowed, so that by reversing the direction of the current, the motion of the needle was also reversed. The general result he expressed as follows:—" That end of the needle which is situated next to the negative side of the battery, or towards which the current of positive electricity is flowing, immediately moves to the westward.

The deviation of the needle is the same, whether the uniting wire, instead of being immediately above the needle, be placed somewhat to the east or west of it, provided it continue parallel to, and always above t. This shows that the effect is not the result of a simple attractive or repulsive influence, for the same pole of the magnetic needle, which approaches the uniting wire when placed on its east side, recedes from it when placed on its west side.

If the uniting wire be placed in a horizontal plane under the magnetic needle the latter is affected to an equal degree as in the former case, but the motions are made in the contrary direction; for the pole of the needle next to the pole of the battery now deviates towards the east.

When the uniting wire is situated in the same horizontal plane as that in which the needle moves, and is at the same time parallel to it, no declination takes place either to the east or west; but the needle is inclined, so that the pole next to the end of the wire at which the negative electricity enters is depressed, when the wire is situated on the west side, and elevated when situated on the east side.

Oersted found that these experiments succeeded equally well if the uniting conductor consisted of one or of several wires, or metallic ribbons, connected together. Neither is the effect altered in its kind, though it may vary somewhat in its degree, when different metals are used. The conductor still exerts this power, although it be interrupted by water, provided the interval between the metals does not extend to several inches in length. The magnetic influence of the wire on the needle is not prevented by the interposition of glass, metals, wood, water, resin, stones, or any other substance that was tried. The effect produced, nevertheless, is referable purely to magnetism, for it is exerted on magnetic bodies only, and has no influence on needles of brass, glass, or gum-lac.

The announcement of the important discovery of Oérsted excited the greatest interest among all the philosophers of Europe, and they immediately occupied themselves in repeating and extending his experiments. Among those who were early distinguished by their zeal and activity in this research were Ampere and Corago in France, and Sir H. Davy and Faraday, in England. So many were the cultivators in this new field of inquiry, and so eagerly did they pursue the path thus unexpectedly opened, that a great number of interesting facts were speedily brought to light; and where all were pressing forward in the same career, it is scarcely possible to adjust the claims to the most important facts.

An attentive examination of what has been already stated on this subject will soon convince us that the magnetic force, which emanates from the conducting wire, is entirely different in its mode of operation from all the other forces in nature with which we are acquainted. It does not act in a direction parallel to that of the current which is passing along the wire, nor in any plane passing through that direction. It is evidently exerted in a plane perpendicular to the wire, but still it has no tendency to move the poles of the magnet in a right or radial line, either directly towards or directly from the wire, as in every other case of attractive or repulsive agency. The peculiarity of its action is that it produces motion in a circular direction all round the wire, that is, in a direction of the tangent to a circle described round the wire in a plane perpendicular to it. Hence, as Mr. Barlow expressed it, the electro-magnetic force exerts a *tangential action.*

When the direction of the current is reversed, the wire still preserving its vertical position, the direction of the section is also reversed; and the circular motions produced correspond to the movements of the hands of a watch with its face downwards; that is still looking towards the positive electrical pole.

The actions of either the descending or ascending electrical current upon the south pole of a magnet are exactly the reverse of those which are exerted on the north pole. On reversing the direction of the current these effects will again be reversed.

It is evident that in the course of experiments on electro-magnetism, the current and magnetic poles may be presented to our observation in a great variety of relative positions; and it will be found not very easy to retain a perfect recollection of the way in which the force should act conformably to the rule above stated. Ampere has hit upon an ingenious method for imprinting this rule more firmly in the memory, and enable us to apply it under a great variety of circumstances. The electric currents are not only characterised as positive and negative, and as flowing in one or other of two directions along the wire that conducts them, but may be actually personified and conceived as endowed with a head and feet, with a face and back, and with a right and left hand.

It is more natural to fix our attention on the current of positive than of negative electricity. In a vertical wire, a descending current will occur to us more readily than an ascending one; or if we imagine ourselves borne along by the current, it would be more natural to conceive ourselves moving with our feet foremost; but if on the contrary, we conceive ourselves to be at rest, we should suppose the current to be passing from our head to our feet. Our face would, of course, be turned towards the magnetic pole to which we are directing our attention; we should attend to the north pole in preference to the south; and the movement with which we are most familiar is that which we perform with our right hand, as in writing, for instance, that is from left to right. Combining these conditions then, we may always recollect that if we conceive ourselves lying in the direction of the current, the stream of positive electricity flowing through our head towards our feet, with the magnet before us, the north part of that magnet will be towards our right hand. If any of these conditions be reversed, the result will be reversed likewise.

The direction of the electro-magnetic force being thus determined, we have next to ascertain the exact law, according to which its intensity varies with relation to the distance of the electric current from the point in which it acts. The most reasonable conjecture we can form on this subject is, that this law is the same with that which is followed in the course of electric and magnetic actions, that the intensity of force is everywhere inversely as the square of the distance. But if this be the real law of action, it must apply to the elementary portions of the two agents which thus mutually act upon each other; or, to adopt the more convenient language of theory, it must obtain only among the elementary particles of the electric and magnetic particles of the electric and magnetic fluids. In the magnet, the action of the latter may be regarded as concentrateed in the points, which are the poles of the magnet; but in the conducting wire, the electric fluid which is passing through it, acts in an equal degree along the whole line of its motion; and admitting the hypothesis of the action being inversely proportional to the squares of the distances of each individual particle, we have to deduce the law which will result from the combined actions of all the points of a line directed upon a point out of that line. Now, it may be mathematically demonstrated, that if the line in question be perfectly straight, and its length be exceedingly great in proportion to the distance of the point on which it acts, then the intensity of action will be inversely proportional, not to the square, but to the simple distance of the point, so that at three times the distance, for example, the force shall be one-third, and four times the distance, one-fourth and so on. That this law is conformable to observation, has been proved by many experiments, in which the intensities of the force at different distances were accurately ascertained by observing the number of oscillations performed by the needle in a given time, and taking the squares of those numbers.

The discovery of the remarkable phenomena of electro-magnetism naturally gave rise to the invention of a variety of hypotheses for their explanation. Professor Oersted conceived that a distinct class of effects resulted during the act of their re-union, which was marked, not only by mechanical agitations among the particles of bodies, by the production of sound, by the evolution of light, and by the disengagement of heat, but also by the disturbance of the magnetic equilibrium. These phenomena seemed to indicate the occurrence of great and sudden changes taking place in the conditions of two powerful agents at the moment of their coalescence, and suggested to Oersted the idea that something analogous to a shock takes place when the fluids rush together from a distance. During galvanic action the separation of the two electric fluids, proceeding without intermission in one part of the apparatus, and their re-union being in like manner effected in perpetual sequence along the conducting bodies which complete the circuit, he conceived that a continued series of shocks took place throughout the whole line of conductors; a condition which he expressed by the term *Electric Conflict.*

If these views be correct, it must follow that the electric fluids, which, whether in motion or at rest, have, when isolated, no apparent influence on magnetic bodies, acquire during their conflict the power of affecting these bodies. This hypothesis was expressed by Oersted in the following words:—"The electric conflict acts only on the magnetic particles of matter. All non-magnetic bodies appear penetrable by the electric conflict, while magnetic bodies, or rather their magnetic particles, resist the passage of this conflict. Hence they can be moved by the impetus of the contending powers. It is sufficiently evident that the electric conflict is not confined to the conductor, but disposed pretty widely in the circumjacent space.

"We may likewise collect that this conflict performs circles; for without this condition, it seems impossible that one part of the united wire, when placed below the magnetic pole, should drive it towards the east, and when placed above it, towards the west: for it is the nature of a circle that the motions in opposite parts should have an opposite direction. Besides, a motion in circles, joined with a progressive-motion, according to the length of the conductor, ought to form a conchoidal or spiral line; but this, unless I am mistaken, contributes nothing to explain the phenomena hitherto observed."

"All the effects of the north are easily understood by supposing that magnetic electricity moves in a spiral line bent towards the right and propels the north pole, but does not act on the south pole. The efforts on the south pole are explained in a similar manner, if we ascribe to positive electricity a contrary motion and power of acting on the south pole, but not upon the north."

The views entertained by Oersted were very generally adopted by philosophers who prosecuted the path of discovery he had laid open.

All the effects of terrestial magnetism may be imitated by distributing wires round the surface of an artificial globe, so as to direct a current of electricity through them. Mr. Barlow, in a paper read at the Royal Society, describes the following experiment, which he made with this view. A hollow wooden globe, sixteen feet in diameter, was furnished with copper wires passing in groves along each parallel of latitude for every tenth degree. When an electric current was made to pass through these wires, in the same direction in each, it was found that a magnetic-needle, properly neutralized with regard to the earth's action, and suspended in different situations near the surface of the artificial globe, arranged itself in positions perfectly analogous to those actually assumed by the dipping-needle in corresponding regions of the earth. It is probable that if we could indefinitely multiply these electric currents on a globe so prepared, the apparatus might be made to represent with great accuracy every circumstance of magnetic dip and direction; and by employing, instead of a magnetic needle, an electro-dynamic cylinder, all the phenomena of terrestrial magnetism might be exhibited, without the intervention of magnetism, by means of electricity alone.

Professor Seebeck, of Berlin, discovered in the year 1822, that currents of electricity might be produced by the partial application of heat to a circuit composed exclusively of solid conductors. The original experiment which he established, was first announced in this country in the Annals of Philosophy. A bar of antimony, about eight inches long, and a half an inch square, was taken, and its extremities connected by twisting a piece of brass wire round them so as to form a loop, each end of the bar having several coils of the wire. On heating one of the extremities for a short time, with a spirit lamp, electro-magnetic effects were produced in every part of a circuit so formed. The electric current thus excited has been termed *Thermo-electric*, in order to distinguish it from the common galvanic current, which, as it requires the intervention of a fluid element as one of its essential components, was denominated *Hydro-electric current.*

The chief evidence we possess of the existence of thermo-electric currents consists in the production of electro-magnetic effects. A compass-needle either within or without the circuit, and at a small distance from it, is deflected from its natural position with regard to the circuit.—Still stronger indications of electro-magnetic action are obtained by placing two ends of one of the metallic arcs in contact with the wires of a galvanometer. The thermo-electric current has also been found to excite contractions in the muscles of a frog; but as far as experiments have yet been tried, it is inadequate to effect chemical decompositions, the ignition of metals, or to exhibit sparks or any other of the phenomena of ordinary electricity.

INFLUENCE OF LIGHT ON MAGNETISM.

Professor Morichini, of Rome, announced his having discovered that steel, exposed in a particular manner to the concentrated violet rays of the solar spectrum, became magnetic ; but the uniform failure of the experiment, when tried by other persons, had created great doubts of the accuracy of the results as reported by Morichini. In the course of some experiments made by Mr. Christie, in the year 1824, he was led to the conclusion that the solar rays actually do exert a sensible influence on magnetism, which is shown by their affecting the vibrations of a magnetic needle exposed to them, quite independently of the effects produced by the heat which they impart. A needle six inches long, contained in a brass compass, but with a glass cover, was suspended by a fine hair, and made to vibrate, alternately shaded and exposed to the sun. He found, from a number of trials, that the vibrations of the needle, when exposed to the sun, ceased in a much shorter time than when they took place in the shade. That this greater slowness of the vibrations was not attributable to a change of temperature, was proved by the needle's being observed to vibrate more rapidly when its temperature was raised by other means.

In the Philosophical Transactions for 1826, we are informed that, in the summer of 1825, Mrs. Somerville was induced, by the unusual clearness of the weather, to investigate the subject. Having at that time no information of the manner in which Morichini's experiments had been conducted, it occurred to her that, if the whole needle were equally exposed to the violet rays, it was not probable that the same influence which produced a south pole at one end, would, at the same time, produce a north pole at the other.

She therefore covered half of a slender sewing needle, an inch long, with paper, and fixed it in such a manner as to expose the uncovered part to the violet rays of a spectrum, thrown, by an equiangular prism of flint glass, on a pannel at five feet distance. As the place of the spectrum shifted by the motion of the sun, the needle was moved so as to keep the exposed part constantly in the violet ray. The sun being very bright, in less than two hours the needle, which before the experiment showed no signs of polarity, had become magnetic, the exposed end having the properties of a north pole.

The season continuing favourable, afforded daily opportunities of repeating and varying the experiments with needles of different sizes and placed in different positions with respect to the meridian, and at different distances from the prism. The result was nearly uniform, and similar to that above stated. It was not found necessary to darken the room, provided the spectrum was thrown out of the direct solar rays.

Mrs. Somerville next endeavoured to ascertain whether the other prismatic rays had the same property as the violet. Needles previously ascertained to be unmagnetic, exposed to the blue and green rays, sometimes acquired magnetism, though less uniformly and less quickly than in the violet ray: when magnetism was thus communicated, it seemed to be equally strong as in the former case. The indigo ray succeeded nearly as well as the violet. The exposed end, in almost every case, became a north pole. In no one instance was magnetism produced by the yellow, orange, or red rays, though in some instances the same needles were exposed to their influence for three successive days; neither did the calorific rays of the spectrum produce any sensible effect.

Pieces of cloak and watch-spring were next tried with similar success, and were even found to be more susceptible of this peculiar magnetic influence than needles, possibly on account of their blue colour, or greater proportional surfaces. The violet rays concentrated by a lens produced magnetism in a shorter time than the prism alone.

Experiments were next instituted by transmitting the solar rays through coloured media. Needles, half covered with paper, were exposed on a stone outside a window, under a blue glass coloured by cobalt, to a hot sun, for three or four hours. They were found to be feebly magnetic; but their magnetism was not permanently retained. In subsequent experiments, by an exposure of needles under the same circumstances, for six hours, a very sensible degree of magnetism was acquired, and remained permanent. The rays transmitted through the blue glass employed in this experiment blackened muriate of silver as powerfully as those transmitted through uncoloured glass; thus proving that it was freely permeable to the chemical rays of the solar spectrum. Green glass was also tried; and the rays which had penetrated it were likewise found to communicate magnetism. The white light of the sun produced no magnetic effect whatever on needles exposed to its influence.

ORIGIN OF TERRESTRIAL MAGNETISM.

SEVERAL causes have been assigned for the magnetic influence which the globe of the earth is found to exercise, not only over the magnetic needle, but also over currents of Voltaic electricity transmitted through conductors. Among the various substances which occupy the interior of the globe, it is extremely probable that chemical actions of different kinds are incessantly occurring. These actions will, for the most part, however, be very slow, and will continue with a certain degree of uniformity for very extended periods of time. They will occur more especially in the superficial strata of the earth, when the combined agencies of water, of atmospheric air, and of heat, are in constant operation. The influence of the solar rays on a surface of vast extent must be very considerable; and excepting in the vicinity of the poles, every portion of that surface is exposed in succession to their action, and acquires, during that exposure, a certain degree of heat, which heat is again lost by nocturnal radiation. Although the effect of the alternate changes of temperature may extend only to a small depth beneath the surface, yet considering their immense superficial extent, they may be sufficient to give rise to thermo-electric currents of considerable power. It has been conjectured also, that these effects may be combined with an influence of another kind, more directly derived from the rotation of the earth on its axis, on the principle that all bodies have been found to exhibit magnetic polarity by rotation.

That electric currents do really circulate in different parts of the solid strata of the earth, is not merely matter of conjecture: the existence of such currents has been lately proved in the most satisfactory manner, by Mr. Fox, in a paper "On the Electro-Magnetic properties of metalliferous veins," which was published in the Philosophical Transactions. Having been led from one theory to entertain the belief that a connexion exists between electric action in the interior of the earth, and the arrangement of a metalliferous vein, he was anxious to verify this opinion by experiment. The first trials he made with this view were unsuccessful; but by persevering in his attempts, he soon obtained decisive evidence of considerable electrical action, in the mine of Huel Jewel, in Cornwall. His apparatus consisted of small plates of sheet copper, which were fixed in contact with ore in the veins by copper nails, or else wedged closely against them, by wooden props stretched across the galleries of the mine. Between two of these plates, at different stations, a communication was made by copper wire, one-twentieth of an inch in diameter, which included a galvanometor in its circuit. In some instances three hundred fathoms of copper wire were employed.

The intensity of the electric currents was found to differ considerably in different places. It was generally greater in proportion to the greater abundance of copper ore in the veins, and in some degree, also, to the depth of the station. This curious fact may possibly afford the miner some useful indications as to the relative quantities of the ore which the vein contains, and also as to the direction in which it is most productive. The electricity thus perpetually in motion, does not appear to be in any effect influenced by the presence of the workmen's and other candles; nor even by the explosions of gunpowder in blasting.

Mr. Fox observes, that ores which transmit electricity have generally some conducting material interposed in the veins between them and the surface; a structure which appears to bear some analogy to the ordinary galvanic combinations. These electrical currents which pervade mines, were found to have various and frequently opposite directions in different parts of the same mine.

The metals are probably not the only substances capable of giving rise to electrical currents in the earth, for it is well known that galvanic combinations may be formed by arrangements of elements that are not metallic. The direction of each current will, of course, be determined by the relative position of the elements from which it is derived; but even if we suppose the arrangement of these elements to be fortuitous, a prevailing current will still result, arising from the difference of their actions; for it is infinitely improbable that, without a designed arrangement, the currents in opposite directions should be exactly equal so as to destroy one another. Irregularities of distribution probably exist with regard to the materials composing the interior of the globe; the resultant electro-magnetic action of the whole combination, being that of which we witness the effect, and which may be considered as due to electrical currents circulating in directions parallel to the magnetic equator round the surface of the earth.

Even in the irregularities incident to the magnetic forces derived from the earth, we may discover the operation of causes which are periodical in their operation. Thus the diurnal and annual changes of the variation, of the needle may be traced to corresponding changes in the position of the different parts of the earth, with regard to the sun, in as far as these electric currents are dependent upon solar influence. The progressive changes in the variation, which embrace longer periods of time, are less easily accounted for, and appear referable to causes which act at greater depths below the surface of the earth ; and are probably connected with chemical changes taking place in the interior of the globe, of which we can possess no certain knowledge.

On the whole, then, it must be allowed that there are strong grounds for the belief that there subsists some mutual connection, or rather an intimate relation and affinity, between the several imponderable agents, namely, *Heat*, *Light*, *Electricity*, and *Magnetism*, which pervade in so mysterious a manner all the realms of space, and which exert so powerful an influence over all the phenomena of the universe.

ELECTRICITY.

A GENERAL idea of a science may be more frequently communicated by a review of the rise and progress of that science, than by any other means. This remark applies to electricity with greater force than to many other branches of knowledge ; and in drawing up the following historical sketch, attention has been paid to the extrusion of matter which has not instruction for its object.

The earliest account of electricity, artificially excited, of which we have any record, is carried as far back as six hundred years before the birth of Christ, when Thales, the Milesian, observed that amber, after having been rubbed, possessed the power of attracting light bodies, such as feathers, &c. We have no proof that much notice was taken of this fact; indeed it would appear of too little consequence to be much regarded; and it does not even seem to have been known that any other substance resembled amber in its attractive property after friction, till about three hundred years afterwards, when Theophratus mentions that a stone, which he called the *lyncurium*, and which is supposed to be the same with what we now call the *tourmalin*, possessed the same peculiarity. From this period commences another chasm in the history of electricity, of nineteen hundred years' duration. The commencement of the seventeenth century may be considered the earliest era at which the science takes its date. The person who first contributed essentially to its promotion was Dr. William Gilbert, who in the year 1600, published a book, which contains a variety of electrical experiments, relative, however, merely to such substances as had the properties of amber, the whole of which class of bodies are now called electrics. These properties as yet excited no general interest; they became not the exclusive object of any one's attention, but only transiently arrested the notice of those whose researches extended to every branch of knowledge, however unpromising and trivial its appearance. After the date of Gilbert's volume, additions continued to be made to the catalogue of electrics, but nothing of moment was observed further, till about seventy years afterwards; when the celebrated Robert Boyle greatly enlarged the number of electrics, and discovered that their effects were much increased by wiping and warming them before they were rubbed; and saw a faint specimen of the electric light, from some diamonds which he had rubbed to give them the power of attraction.

Otte Guericke, of Magdeburg, who was contemporary with Boyle, and justly famed as the inventor of the air-pump was eminently successful in his electrical pursuits. He constructed a globe of sulphur, to which he applied his hand while it was whirled round in a proper frame, by which means he had the pleasure of observing that he obtained an accumulation of electricity far beyond any former example, and which enabled him to perform a great variety of electrical experiments with considerable advantage. He discovered electrical repulsion, and not only saw in a state of intensity the electric light of which Boyle had seen but a glimpse, but heard the sound with which it is accompanied. He also observed that a feather when repelled by an excited electric, always keeps the same side towards the body which repels it, and that, after having been repelled it is not again attracted till it has touched some other body.

The torch of investigation into this subject, had now become distinctly lighted, and the number of discoveries increasing with considerable rapidity, kept curiosity alive, though with many fluctuations. Dr. Wall, by rubbing amber upon a woollen substance in the dark, produced considerable quantities of electrical light accompanied by a crackling noise; and he remarked that "this light and crackling seems, in some degree, to represent thunder and lightning." In 1709, appeared a treatise by Hauksbee, which possessed great merit. He repeated and confirmed the experiments of Dr. Wall, and noticed the sensation communicated to the hand by the electric spark.

He introduced the important improvement of using a glass globe instead of a sulphur one, and among other new experiments, relates a method of rendering opaque bodies transparent by means of electricity. He lined more than half of the inside of a glass globe with sealing wax; and having exhausted the globe, he put it in motion; when applying his hand to excite it, he saw the shape of all parts of his hand distinctly, on the concave superficies of the wax within just as if only uncoated pure glass had been interposed between his eye and his hand. The lining where it was spread the thinnest, would but just allow the sight of a candle through it in the dark; but in some places the wax was at least the eighth part of an inch thick; yet the whole appeared equally transparent. The wax did not adhere to the glass in all places, but this seemed an immaterial circumstance. Pitch answered the purpose as well as sealing wax.

Sir Isaac Newton's discoveries attracted so much attention that electricity was kept for a time in the back ground; but soon after the decease of that great man, the opening that appeared for new discoveries in it again brought it forward. Hitherto the distinction between electrics, such as amber, glass, &c., which were excited by rubbing, and those bodies which were only capable of receiving electricity, appears to have been scarcely thought of. The distinct view of it was accidentally obtained by Stephen Grey, in 1729. After many ineffectual attemps to excite an electric power in metals, by heating, rubbing and hammering, he recurred to a suspicion he had for some time entertained, that, as a glass tube, when rubbed in the dark, communicated its light to various bodies, it might possibly at the same time communicate to them an electricity or power of attracting light bodies. To examine into this matter, he provided himself with a glass tube, three feet five inches long, and nearly one inch and two-tenths in diameter. To each end was fitted a cork, to keep the dust out when the tube was not in use. His first experiments were made with a view to determine whether the tube would attract equally well with the ends closed by corks, as when they were open. In this respect there was no difference, but he found that the corks attracted and repelled light substances even with rather more power than the tube itself. He then fixed an ivory ball upon a stick of fir about four inches long, and thrusting the end of the stick into one of the corks, he found that the ball obtained a strong power of attraction and repulsion. He varied the experiment, by fixing the ball upon long sticks, and upon pieces of brass and iron wire, and always obtained the same result; also when he suspended the ball by a packthread from a balcony twenty-six feet high, he still found at this and all other heights, that by rubbing the tube, the ball acquired the same power as in the first experiment.

Grey's next attempt was to ascertain whether electricity could be conveyed horizontally as well as perpendicularly. With this view he fixed a cord to a nail which was in one of the beams of the ceiling, and made a loop at that end which hung down, he inserted his packthread with the ball at the end of it, through the loop of the cord, and retired with the tube to the other side of the room, but in this state he found that his ball had no power of attraction. A friend of his, to whom he related his disappointment, suggested that the supporting packthread, from its coarseness, might intercept the electric power, and proposed to substitute a thread of silk. Upon this change being made in the apparatus, the experiments (which were made by Grey and his friend conjointly,) completely succeeded, and the ivory ball showed signs of electricity at the distance of 147 feet from the glass tube. In subsequent experiments they increased the conducting cord, till at length the silken thread supporting it broke. As they attributed their success, since the adoption of the silken thread, entirely to the fineness of that material, they naturally conjectured that brass or iron wire would be still more advantageous; upon making the trial, however, they were completely disappointed, for they found that the ivory betrayed not the slightest evidence of electricity. They therefore again resorted to the use of silk, but used it thicker than before; and by this means conveyed the electric power, without any apparent diminution to the distance of 765 feet.

Such were the experiments which immediately led to the important truth, that though a great number of bodies had the power of conducting the electric energy, yet there were other bodies which entirely stopped its course; and as the former were called *conductors*, the latter were called *non-conductors*. It was soon found that those bodies which showed signs of electricity by rubbing were called non-conductors, and that those which could not be brought to this state, were conductors. Grey continued a zealous electrician to the period of his death, and made many interesting discoveries. In particular, along with his friend, he discovered the method of insulating bodies which were electrified, by placing them upon a non-conducting body, and thus preventing the electricity they have received from immediately flying off.

The grand discovery made by Grey and his friend had been announced but a short time, before another, scarcely less important, was made by Du Fay, who was intendant of the French king's gardens. It arose from casually observing, that though an excited glass-tube repelled a piece of gold leaf, yet an excited piece of gum copal eagerly attracted the same material.—Du Fay found, upon trial, that sealing-wax, sulphur, resin, and a number of other substances, produced the same effect as gum copal. To the electricity of those substances which attracted the gold leaf after excitation he gave the name of the *resinous* electricity, as they were most of them resins; and to the electricity of glass he gave the name of the *vitreous* electricity, for he entertained not a doubt but their nature was as opposite as their effects. Among other experiments, he found it impossible to excite a tube in which the air was condensed; and in repeating Grey's experiments, with a packthread, he perceived that they succeeded better by wetting the line. Hair being a non-conductor, Grey had insulated and electrified a boy by suspending him with hair lines; on this, Fay, in repeating this experiment of the effects of electricity on this animal body, suspended himself by silken cords; in this situation, sparks of fire were drawn from him, on his being touched by any one, and both he and the other person felt a sharp pain at the instant of contact, which was accompanied by a snapping noise.

When another person, by holding a rod of metal, touched the one that was electrified, the spark was drawn as before. From this instance of the accumulation of electricity, and its being drawn off by metal, Grey inferred, and in fact, his former experiments in electrifying insulated substances, has proved, that electricity might be collected in metal, as well as the animal body, and drawn off, during a short interval, as it was wanted. This suggested to him the propriety of that part of an electrical machine now called the prime conductor, which he formed by suspending a piece of metal near his excited glass tube, and was enabled to draw sparks from it. The method of making the prime conductor in the form of a tube was first adopted in Germany, in 1742, where the use of the globe, invented by Hauksbee, was revived, and the conductor was at first suspended by a man standing upon casks of resin, but afterwards its was suspended by silken lines. In Germany, also, about the same time, a woollen rubber was used instead of the hand to excite the globe.

Electricity had now become a part of philosophy, and it had become the duty of some to study that they might teach it; whilst others, who were disposed to the acquisition of knowledge, were incited by the desire of proving what others had asserted, or the higher motive of finding out something new. In this conflict of exertion a discovery was made that may justly be considered as forming an epoch in the history of science, which it immediately raised to an extraordinary degree of estimation. This discovery consisted in the art of accumulating electricity, by what is now called the *Leyden phial.* Towards the close of the year 1745, Von Kleist, dean of the Cathedral of Cammin, made an experiment, of which he sent the following curious account to a friend in Berlin. "When a nail, or a piece of thick brass wire, &c., is put into a small apothecary's phial, and electrified, remarkable effects follow: but the phial must be very dry and warm. I commonly rub it over beforehand with a finger on which I put some pounded chalk. If a little mercury, or a few drops of spirits of wine are put into it, the experiments succeeds the better. As soon as the phial and the nail are removed from the electrifying glass, or the prime conductor to which it hath been exposed is taken away, it throws out a pencil of flame so long, that with this burning machine in my hand, I have taken above sixty steps in walking about my room. When it is electrified strongly, I can take it into another room, and there fire spirits of wine with it. If, whilst it is electrifying, I put my finger, or a piece of gold which I hold in my hand, to the nail, I receive a shock which stuns my arms and shoulders. A tin tube, or a man placed upon electrics, is electrified much stronger by this means than in the common way. When I present this phial and nail to a tin tube, which I have, fifteen feet long, nothing but experience can make a person believe how strongly it is electrified. Two thin glasses have been broken by it." In this experiment, as the phial was of small dimensions, and as the circumstances essential to its greatest effects, were not combined, because they were unknown, the power of the electricity accumulated was inconsiderable; but, soon afterwards, the art of giving a strong shock was discovered in Holland, because the vessels employed happened to be larger. As it was known that the air, or the partial floating it in it, abstracted the power of electrified bodies, so that even insulation was no remedy against their being in a short time deprived of it, an idea suggested itself to Muschenbrok, and some of his friends, that if the electrified body were entirely surrounded by a non-conductor, the dissipation of the electricity would in a great measure, be prevented. To realise this idea, a quantity of water was put into a bottle, and electrified till it was thought to be fully charged; but here the original invention of the experiment was lost sight of, by an unexpected result which swallowed up all their attention. Happening to hold the bottle in one hand, while he endeavoured to disengage it from the conductor with the other, he suddenly received a shock, which shook many of his joints, passed through his breast, and in a great degree, stunned and terrified him. In this manner was first discovered, what still continues to be called the *electric shock.* It excites a smile, to observe the terms in which the shock is spoken of, by several of those who first submitted to its effects. One who tried the experiment with a thin bowl, wrote to his friend afterwards, that he felt himself struck in his arms, shoulders, and breast; that he lost his breath for a time, and did not feel himself well again for the space of two days. He adds, that he would not have taken a second shock for the whole kingdom of France. Other philosophers, however, were found, who had the resolution to take several shocks of great intensity; and one of the most hardy wished that he might die by the electric shock, in order that his death might furnish an article for the memoirs of the Parisian Academy.

After the art of giving a shock by means of a phial or jar had been discovered, the art of combining several jars, so as to unite their powers in one discharge soon followed, and this improvement constituted what is now called a *Battery*. It was made by Dr. Franklin, and resulted from his reflections on the phenomena of the Leyden phial with a conducting substance which communicated by a wire with the person who discharged it, the strength of the shock was exceedingly increased; and that unless some conducting substance was in contact with the outside of the jar, no charge could be given. Dr. Franklin, in accounting for this circumstance, suggested the idea that a charged phial or jar contained no more electricity than before; but that as much was taken from one side as the other had above its natural portion, and that to discharge it, nothing more was necessary than to make a communication between the two sides, and the equilibrium being by this means restored, no signs of electricity remained. He also demonstrated by experiments, that the electricity did not reside in the coating, as had been supposed, but in, or upon the glass itself. After a phial was charged he removed the coating, and found that upon applying a new coating, the shock might be received. When to any body or surface, was attributed the property, according to this theory, of having more than its usual portion of electricity, the Doctor proposed to distinguish its state by the term *plus* or *positive;* when the body or surface had less than its usual share of electricity, its state was distinguished by the term *minus* or *negative.* These terms answered the same purpose and expressed the same things as those of vitreous and resinous, but they were supposed to be so much more appropriate, that their admission into the language of the science soon became complete. It may only therefore be necessary to remark here that bodies electrified plus or positively, are those possessed of vitreous electricity; while those electrified minus or negatively, are possessed of what was termed the resinous electricity. The former seek every opportunity of imparting, and the other of receiving electricity. This consideration of the subject induced the supposition, that if the insides of several jars were connected by means of a conducting substance, and their outsides connected with each other in like manner, they would receive and impart a charge like a single jar, with the difference only of power, which would be increased in proportion to their number and size; and thus a battery of any force could be obtained. By a battery it was found that small animals might be instantly killed, as if struck by lightning, and these convincing examples of its power induced philosophers, where life was concerned, to be more cautious in the use of it than they had been with the jar; but experiments of other kinds were prodigiously multiplied. It was proved that the electric matter might be conveyed to distances much exceeding what had yet been conjectured; Dr. Watson, Bishop of Llandaff conveyed it four miles, a distance which it traversed instantaneously. In another experiment made by the Doctor the electric matter was conveyed by a wire through the river Thames, and spirits were kindled by it after it had run this watery circuit. In other experiments it was conveyed nine miles, and a shock has been sent through 1800 men with a force inconceivably rapid.

The field for electrical experiments had now become very extensive, but there still wanted data that might lead to some knowledge of the nature of the principle thus brought into action, and of the various circumstances that were essential to its production. Dr. Watson, however, made some experiments which tended to these points. Having rubbed a glass tube while he was insulated, by standing on a cake of wax, in order to be electrified, he found that no snapping could be drawn from him by another person who touched any part of his body; but if a person not electrified held his hand near the tube while it was rubbed, the snapping was very sensible. He also observed that if an electrical machine, and the person who turned it, were suspended by silk, no fire was produced; but if he touched the floor with one foot, the fire appeared upon the conductor. From these and other experiments of a similar nature he inferred, that glass tubes and globes only afford the means of obtaining the electrical energy, which does not reside in them, but is derived by them from some external source.

Dr. Franklin's explanation of the phenomena of the Leyden jar, and positive and negative electricity, was given in the course of a correspondence with Mr. Collinson, in England, to whom he also communicated a curious and important observation on the power of points in drawing and throwing off the electric matter. The first intimation of the latter particular he derived from one Thomas Hopkinson, who electrified an iron ball of three or four inches in diameter, with a needle fastened to it, expecting to draw a stronger spark from the point of it; but this expectation was entirely frustrated.

The attention of those inclined to philosophical pursuits in Philadelphia, had been directed towards electricity by the care of Mr. Collinson, who in 1745, had sent to the Library company in that city, an account of the extraordinary experiments then performing in Europe, together with a tube, and directions for its use. But Franklin's eagerness in the research, and his success in making discoveries, exceeded that of all his friends. In 1749, he suggested an explanation of the phenomena of thunder-gusts, and of the Aurora Borealis, on electrical principles;

he pointed out many particulars in which the lightning and electricity agreed; and in adverting to the power of pointed rods in drawing off lightning, he supposed that pointed rods of iron fixed in the air when the atmosphere was loaded with lightning, might, without noise or danger, draw from it the matter of the thunder-bolt into the body of the earth. He says, "The electric fluid is abstracted by points. We do not know whether this property be in lightning; but since they agree in all the particulars in which we can already compare them, it is not improbable that they agree likewise in this: let the experiment be made." The earliest observation, it will be recollected, on the similarity of electricity and lightning, was made by Dr. Wall. On the supposition of the identity of lightning and electricity, Franklin immediately saw and pointed out, that houses and ships might be secured from lightning by pointed iron rods, which should rise some feet above the most elevated part of them, and descend some feet into the ground. But while he postponed the completion of his views, on account of the want of a proper building in Philadelphia for his purpose, they were realized in France, by the following means, and produced incredible surprise.

Franklin having communicated regular accounts of his proceedings and theories to his friend Collinson, who published them for the information of the world, they were soon extensively circulated, and translated into different languages. In France the principles of Franklin, and several of the experiments by which they were supported, soon became familiar to some of the principal philosophers, and several of them, among whom were D'Alibard, and De Lor, determined separately to undertake the experiment. Franklin had proposed for bringing lightning from the clouds. D'Alibard prepared his apparatus at Mary-la-ville, about five or six leagues from Paris: it consisted of an iron rod forty feet long, the lower extremity of which was brought into a sentry-box, where the rain could not come; while on the outside it was fastened to three wooden posts by long silken strings defended from the rain. In his absence he entrusted the care of the machine to a joiner of the name of Coissier, a man of sence and courage, whom he furnished with directions how to proceed in case of a thunder-storm. On the 10th of May, 1752, Coissier heard a clap of thunder between two and three in the afternoon. He ran to the apparatus, for D'Alibard was then absent, and drew sparks from the rod, in the presence of several witnesses. Eight days afterwards, De Lor proved equally successful with his apparatus.

While the laurels with which posterity should crown the memory of Franklin were thus springing up in Europe, where his character now became emblazoned with a general admiration of which he was ignorant, he had himself devised means of easy access to the elevated regions of the air. He concluded that a pointed rod of a moderate height would not answer, and therefore did not try one; but it occurred to him that a common kite, such as children amuse themselves with, would reach any height he wished. He accordingly prepared one of silk, that it might not be injured by rain, the straight piece of wood up the middle of it was pointed with iron, and at the first approaching thunder-storm, he went to a convenient situation for raising it. He was assisted by his son to whom alone he communicated his intentions, possibly with a view to avoid the appearance of premature boasting if he should be unsuccessful. The string of the kite was of hemp as usual, except at the lower end, which was of silk. Where the hemp terminated was fastened a key. After the kite had been raised, a thunder-cloud passed over it; but no electricity appeared. Disappointment appeared to be impending; when suddenly some loose fibres of the string appeared to stand erect and to avoid one another, as if they had been suspended by the conductor of a common electrical machine; he presented his knuckle to the key, a strong spark ensued, and as soon as the string became wet, the supply of electricity became copious. He afterwards prepared an insulated iron rod, to draw the lightning into his house, and by means of real lightning, he performed all experiments usually executed by means of electrical machines. This memorable experiment was tried in June 1752: the French philosophers had therefore the precedence in point of time; but they only trod in the path which Franklin had explicitly pointed out.

When the method of giving the electric shock had just been discovered, such was the influence of the feelings it inspired, that many of those who received it appeared to think no terms too extravagant to convey an idea of the violent effects of a charge which may be borne by a child; but now the time for real terror had arrived; and many who incautiously adventured to bring down the ethereal fire, suffered much by violent shocks, while they incurred the most eminent hazard. In one instance a fatal catastrophe ensued, and we shall record it for the sake of strongly impressing upon the young electrician the necessity of caution. On the 6th of August, 1753, Professor Richman, of Petersburg, was making experiments on lightning drawn into his own room. He had provided himself with an instrument for measuring the quantity of electricity communicated to his apparatus, and as he stood with his head inclined to it, Solokow, an engraver, who was near him, observed a globe of blue fire, as large as his fist, jump from the instrument, which was about a foot distant, towards his head. The professor was instantly dead, and Solokow was also much hurt. The latter could give no particular account of the way in which he was effected; for, at the time the professor was struck, he stated, that there arose a kind of steam or vapour which entirely benumbed him, and made him sink down to the ground, so that he could not even remember to have heard the clap of thunder, which was very loud. The globe of fire was attended with an explosion like that of a pistol; the instrument for measuring the electricity was broken to pieces, and the fragments thrown about the room. Among other effects of the lightning in the chamber, the door-case was found to be half split through, and the door torn off, and thrown into the room. A vein was opened in the professor's body twice, but no blood followed; after which attempts were made to recover life by friction, but in vain; upon turning the body with the face downwards, a small quantity of blood ran out at the mouth. There appeared a red spot on the forehead, from which came some drops of blood through the pores, without breaking the skin. The shoe belonging to the left foot was burst open, and on uncovering the foot, at that part was found a blue mark; whence it was inferred that the electric matter, having entered at the head, made its way out again at that foot. Upon the body, particularly on the left side, were several red and blue spots, resembling leather shrunk by heat; and many more became visible over the whole body, particularly over the back. That upon the forehead changed to a brownish red; but the hair of the head was not singed. In the place where the shoe was unripped, the stocking was entire; the coat also was wholly uninjured, and the waistcoat was only injured on the fore-flap where it joined the hinder. On the back of Solokow's coat appeared long narrow streaks, as if red hot wires had burned off the nap. In forty eight hours the professor's body was so much corrupted, that the removal of it was exceedingly difficult.

But it has been left to our own times to effect the most important discovery of the utility of electricity

—the electric telegraph: by which an instantaneous communication is established between every town and village of any consequence throughout the United Kingdom. This invention was finished in 1848; it is conducted by means of five wires of zinc and copper laid in tubes under ground, and connected with metallic plates at the various stations of each town. By this discovery, intelligence is immediately conveyed throughout the length and breath of the land. For example, when her majesty Queen Victoria opened her parliament in 1848, the printers in various parts of the kingdom, hundreds of miles distant from London, were actually employed in putting her speech in type while she was speaking. The speech was telegraphed as it was delivered, six or eight words at a time; and the inhabitants of the remotest districts were gratified in having it in their power to peruse the speech from the throne, almost as soon as the denizens of London themselves; and now, by means of the submarine telegraph between Dover and Calais, intelligence is received from and forwarded to the Continent with equal rapidity.

We had scarcely ceased to wonder at the achievements of the electric telegraph,—conveying intelligence between places, hundreds of miles apart in the twinkling of an eyelid, when we were called upon for wonderment at a still more extraordinary invention—it is that of the "*Electric Light.*" Several trials of this light have been made; and it is averred that it will supersede the use of all other artificial lights; that by its intense brilliancy darkness will be dispelled; that in point of safety, cheapness, and efficiency, it will far surpass all other inventions for illuminating; that there is no smoke, no vapour; that it can be lighted up and extinguished by the touch of a child: that it is inexhaustible, and may yet be put out in a moment. It is expected to be seen careering as a pillar of fire on the railways, and spreading its rays across the turbulent waves from the distant steamer. It will be from the lighthouses a gem bound on the dusky brow of night. Such are the fond expectations. Patents have been secured, and companies are in course of organization for dispensing the blessings of this wonderful invention.

REMARKS ON ELECTRICITY.

Electrical Clock.—This machine, which is exhibited in Geneva, is especially remarkable on account of its extreme simplicity, is composed only of a pendulum, a large wheel, two escapements, and a quadrature. Such are the visible parts; we must, however, suppose that a pinion and a wheel make the communication between the great wheel and the quadrature. The pendulum at each vibration, causes one of the escapements to advance the great wheel one tooth, which, after this movement has a pause making the dead round. As there is no metallic moving power to set the machine a-going, we find, on examining, what keeps up the motion, that the pendulum, which is almost out of proportion with the clock, descends into a case; and there, at each vibration, the ball or bulb, which is furnished with a conductor, approaches atternately two poles, to which voltaic piles supply their portion of electricity. So that the pendulum, when once put in motion, retains it by means of the electricity alternately drawn from the two poles. This machine, which is equally simple and ingenious, is worthy of the attention of the artist. Perhaps other interesting results may be obtained by employing the electric fluid as a moving power, however slight the force such an agent may seem capable of communicating.

In drawing up the preceding sketch, we omitted to mention that although the chief technical terms belonging to the subject have been in a good measure explained, but to render the reference to them more easy, we shall here explain them more fully.

All bodies admit electricity to pass through them, such as gold, silver, copper, platina, brass, iron, quicksilver, lead, &c., are called *conductors of electricity;* the same bodies are often called *non-electrics.*

All bodies which are impermeable to electricity, such as glass and vitrifications, precious stones, amber, jet, sulphur, wax, silk, cotton, resinous substances, &c., are called *non conductors of electricity;* they are also called *electrics* with almost equal frequency.

We have already observed that electricity is found to be of two kinds, which are generally distinguished by the appellations of positive and negative. In what the difference of these electricities consist has been much contested; but we coincide with Dr. Franklin, who argues that when bodies are electrified positively, their electricity is redundant or greater than their natural quantity; when they are electrified negatively, he supposes that part of their natural quantity of electricity is abstracted.

The cause of electricity is supposed to be a fluid, which is therefore called the *electric fluid.*

Any electric body, the surfaces of which possess the two different electricities, is said to be *charged.*

ELECTRICAL APPARATUS.

WE will now notice shortly, the principal machines by which electricity may be accumulated and accommodated to the purpose of experiment, and then proceed to the consideration of the theory of electricity.

The simplest kinds of electrical apparatus, such as glass tubes, rolls of sealing wax, cakes of resin, &c., require no separate description, as they will be sufficiently understood by their names.

The cylinder machine, which is most commonly used, is better known by the name of the *Electrical Machine.* The cylinder, conductor, rubber, and pillars should, when it is in use, be perfectly dry, and to ensure this they should be rather warm than otherwise. The machine is supposed to be in order, and a communication made between the rubber and the ground, by means of a chain or piece of wire attached to it; on turning the cylinder, the electric fluid, in the form of sparks, accompanied by a snapping noise, may be drawn from the prime conductor, by presenting to it the knuckle or any blunt uninsulated conductor. If any pointed body, such as a needle, be presented to the conductor while the cylinder is turned a star or globule of light will be seen at the point but no noise will be heard.

The *Plate Machine.*—When glass was first used a the electric of a machine, the form of a globe wa adopted; but afterwards the cylinder, as above mentioned, was found more convenient and economica Dr. Ingenhouz, however, introduced the use of a fl cylinder plate, turning on a horizontal axis in tl manner of a wheel, and the machine thus construct has many good properties; it is simple, elegant, co pact, and powerful. The most powerful electri machine ever made was of this description, for t museum at Haarlem.

The *Electric Jar.*—Electricity, derived from conductor of a machine, is accumulated, and for a ti preserved by means of electrics coated with condu ing substances. Glass is the electric most usually ployed, and the form generally selected is that jar. "Leyden phial" is synonimous with "ele jar." In selecting jars for electrical purposes, should be taken to have the glass equally thi every part. When a jar is defective in this re it will break in the thinnest part, if strongly ch

The *Electric Battery* is formed by combi number of jars, in a wooden box of a size ada the number of jars it is to contain, not quite as the jars are high, divided into compartmer of which will receive only one jar. A powerful battery may be formed of wine bottles; but they must be coated and furnished with a wire in the same manner as ordinary jars.

Electricity may be obtained in a great number of ways as well as by friction, insomuch that we have reason to consider this power as a universal agent of nature. 1. It is produced by the heating or cooling of a variety of substances. 2. By the evaporation and condensation of vapour. 3. By the natural changes in the atmosphere. 4. By the will of certain animals. 5. By the action of certain bodies on each other when in contact.

The *Electricity evolved by heating and cooling* has been sometimes called spontaneous electricity. If sulphur be melted in an earthen vessel, and then left to cool in the same vessel upon conductors, it will, upon being taken out after it is cold, be found strongly electrical; but if left to cool upon electrics, no such effect ensues. If sulphur be melted in a glass vessel, and left to cool, both the glass and the sulphur acquire a strong electricity; but the electricity is stronger when they are cooled upon electrics than when cooled upon conductors; and if the glass vessel be coated with metal, the electricity required is strongest of all.

The *Electricity evolved in evaporation and condensation of vapour.*—Volta discovered that bodies from which water had evaporated showed signs of negative electricity, by which it appears that water, in the state of vapour, retains a larger portion of the electric fluid than in the state of water. Exceptions have, however, been taken to this rule: 1. If water be evaporated by contact with a red hot piece of rusty iron, it will leave the iron electrified positively; but the iron will be negatively electrified if not rusty. 2. If water be evaporated by throwing into it impure red hot glass, (such as the glass of bottles,) the vessel, or the remaining water will be electrified positively.

Atmospheric Electricity.—Since Franklin and his contemporaries first drew lightning from the clouds, and exhibited with it the whole series of electrical phenomena, no experiment has ever been devised, which could throw a shadow of doubt on the identity of lightning and electricity. Accordingly, lightning is only to be considered as a name for a vast accumulation of electricity; or electricity as a name for small quantities of lightning. When we consider the sharpness of a spark supplied by a few inches of glass, we cannot hesitate to allow that the effect of the spark drawn from a thousand acres of cloud must be violent in the extreme.

The atmosphere almost at all times affords signs of electricity, and it may be proper to advert here to the means commonly used to discover it. Cavallo's electrometer is a very useful instrument for this purpose. By holding it up a few feet above the ground the pith-balls will gradually diverge, and the kind of electricity may be ascertained by touching it with any exited electric, observing that the electricity of the instrument in this case, is the contrary of that of the atmosphere.

Instruments have been invented, called multipliers and doublers of electricity, intended to be used where extreme delicacy of examination is proposed; but the action of these is rather a dubious nature, and we shall pass on to a short notice of

The *Electric Kite*, which, as we have already observed, differs in no respect from those used among children, except that the paper is covered with drying linseed oil, to prevent its being destroyed by the rain, and a slender wire is interwoven with the string to render it a better conductor. It is, however, doubtless known to every one, that there is a considerable difference among children's kites in their flying properties; some of them, under every favourable circumstance of wind and size, can scarcely be raised or kept aloft by any exertion, so that the pertinacity of infantine perseverance, in affairs of sport, is almost exhausted in attending to them. We shall therefore give the proportions that will certainly answer well, and as these may be observed with so much facility, we presume it will not be required that we should devote a sentence to the consideration of how much they may be deviated from without hazarding the convenience of raising the machine. The straighter and the bow, should, when the latter is open, be of the same length, reckoning the length of the straighter from the place where it is notched to the bow. By this means when the bow is in its place, the cord which connects its extremities, passes over the straighter at the distance of one-third of its length of the latter from its end; and the tapering of the kite therefore commences at two-thirds of its length from its pointed extremity. The cord to which the cord for raising the kite is attached, is fastened by both ends to the straighter, and at one-sixth of the whole length of the kite from the extremity. The length of the cord may be equal to that of the straighter. The cord, the length of which regulates the distance of the flight of the kite, must be attached to such part of the cord fastened to the straighter, that the kite if suspended by it, without a tail, shall remain horizontal, that is, it shall be just opposite the centre of gravity of the kite; and if the weight of paper on each side of the straighter is not equal, it should be made so by putting on additional pieces. The tail of the kite should be at least seven times the length of the straighter, and it should be loaded in about twenty different places with some such material as rolls of paper, and a ball or heavy roll of the same kind at the extremity. The proper weight of the tail is easily ascertained by a few trials. The straighter should be made of fir, and the bow cannot be made of anything better than a light hoop. A kite thus constructed will be easily raised with a moderate wind to a great height. A kite four feet high is very convenient for electrical purposes.

In an electrical point of view the whole power of the kite consists in the string; it is, therefore, of little use to coat the straighter with tinfoil, or tip it with iron as some have proposed; but it is important to make the string a good conductor. For this purpose the simplest mode is to wet it; but it is better still, to use with two threads of common hemp one of the copper threads used for trimmings.

The highest idea which the ancients could form of Omnipotence comprised the exclusive ability of directing the thunderbolt; the power of which they considered to be absolutely irresistible, and the command of it immeasurably removed from human control. If then weak man venture to interfere with this astonishing agent of Nature, let him remember its tremendous power, and not, for a moment, forego the precautions that ensure his safety. In serene weather there never is any danger in raising the kite; but it is always unsafe to raise it during a thunder-storm, or while black clouds are hanging overhead; for the quantity of electricity brought down will often be very great, although there may be no thunder. When the electricity during a storm is intended to be observed, the kite should be raised while the air is yet tolerably clear; at the lower end of the conducting line should be attached three or four yards of silk cord covered with wax, that it may not, by getting damp, readily become a conductor. From the termination of some other part of the conducting line, a chain of sufficient length to reach the earth should be fastened, or instead of it, when jars are to be charged, and other experiments are to be made, a slender wire may reach from the conducting line to an insulated prime conductor. This conductor should be furnished with a quadrant electrometer, that the strength of the electricity may be determined by inspection. The wire connecting the string of the kite and the prime conductor should not be stretched, to prevent the motions of the string or the conducting line from throwing down the conductor. In making experiments with an insulated string, especially when a storm is apprehended, or actually present, it would be proper to have a rod of iron or some other good conductor in direct communication with the earth, and within an inch or two of the string, so that notice would be given of the descent of any unusual quantity of electricity by the snapping between the conductor and the string, and the operator would have time to provide for his safety.

After experiments with the electrical kite had proved that lightning could be drawn from the clouds, it ceased to be a doubtful question whether buildings might not be saved from destruction by lightning, if they were furnished with proper conductors. But a controversy arose as to the best form of them. It was maintained by one party that they should have blunt terminations; by another that they should be pointed. A number of experiments, made under the inspection of the Royal Society, decided the question in favour of pointed conductors, and no others are now in use.

An effective conductor should rise eight or ten feet above the highest part of the edifice it is intended to secure, and should terminate in several short branches, each of which must be pointed, in order that if one or more be melted by the lightning, the rest may perform the office assigned them. The conductor should not be smaller than half or three-quarters of an inch in diameter, and as its effects would be injured by rust, the upper part of it should be copper. It should not descend very close to the side of the building, and care should be taken to direct it from the house towards the foundation, and terminate, if possible in moist earth or water under ground.

Personal security, during a thunder-storm forms another object of important consideration. Persons apprehensive of lightning should sit in the middle of a room, not under a metal lustre or any other conductor, and place their feet on another chair. A precaution of this kind is the easiest that can be observed, and ensures a high degree of safety. But the place of most perfect safety is the cellar, and especially the middle of it; for when a person is lower than the surface of the earth, the lightning must strike it before it can reach him. It is, therefore most probable that it will become immediately diffused and not enter the cellar, especially if it be not damp.

The best situation for a person who happens to be in the fields during a thunder-storm, is, not immediately under a tree, but within a short distance of it, as the lightning generally strikes first the highest and best conductors.

Animal Electricity. There are three species of fish which possess the power of giving an electrical shock; viz., the *torpedo*, the *gymnotus electricus*, and the *silurus electricus*.

The *Torpedo* has been known from the most ancient times, but the wonderful accounts of its power were till recently regarded as fabulous by those who had not witnessed them. The torpedo is a flat fish, of the ray tribe, very seldom exceeding twenty inches in length and twenty pounds in weight. It inhabits the Mediterranean and the North Seas. If the torpedo either in the water or out of it, be touched with one hand, it generally communicates a slight shock to the hand; but the sensation is felt in the fingers of that hand only. If the torpedo be touched with both hands at the same time, one being applied to its under, and the other to its upper surface, a shock will in that case be received, which is exactly like that given by the Leyden phial. The animal is supposed to stupify its prey by this singular faculty.

The *Gymnotus Electricus*, or the electrical eel, is generally of the length of three or four feet, of an unpleasant appearance, and much like a large eel, but thicker in proportion to its length, and always of a blackish brown colour. It is found in the hot climates of Africa and America. This animal has the power of giving an electric shock to any person, or to any number of persons who join hands together, the extreme person on each side touching the fish.

Of the third fish capable of giving the shock, but few particulars are known. It is called the *Siluras Electricus*, and is found in the rivers of Africa. It is sometimes found to exceed twenty inches in length. The body of this fish is oblong, smooth, and without scales; the electric organ seems to be towards the tail, where the skin is thicker than on the rest of the body. It is merely said in general that it has the power of benumbing like the torpedo, but we have seen no details of experiments made with it.

Electrical Cohesion.—The force with which electrified bodies remain in contact, has, instead of attraction, been called electrical cohesion. An amusing instance of this is seen in Symmer's experiments on silk stockings. He had been accustomed to wear two silk stockings on the same leg, one of them white, the other black. When these stockings were drawn off together, nothing remarkable appeared; but if, while they were both on, he rubbed his hands several times over them, and then drew off the outer or black one by itself, he heard a crackling noise, and in the dark perceived sparks of fire between them. When the stockings were separated, and held at a distance from each other, both of them appeared to be highly excited; the white stocking positively, and the black stocking negatively. While they were kept at a distance from each other both of them appeared inflated to such a degree that they exhibited the entire shape of the leg. Two black or two white repelled each other with considerable force; but a white and a black one, would, if permitted, rush together with surprising violence; their inflation subsiding at the same time, and entirely ceasing when they were in contact. On separating their electricity was renewed. At first Symmer found that it required a force of from one to twelve ounces to separate them; and at another time they required seven ounces to separate them, which was twenty times the weight of the body that supported it. Electrical effects will be obtained by rubbing with the hand any small pieces of black and white silk in like manner.

Medical Electricity.—In the infancy of electricity, accounts were multiplied of cures next to miraculous, performed by means of this newly-acquired power; but upon closer investigation it appeared that most of these either had no existence, or were exaggerated by weak or interested men, and that mischief rather than benefit had been produced. The error of the early electricians consisted in giving strong shocks, which experience has shown to be nearly in all cases improper. "One thing, however," says Cavallo, "appears to be a little remarkable in favour of electricity as a medicine, that though it has often fallen into the hands of very unskilful and injudicious persons, who have applied it at random in all cases, without being capable of distinguishing either the nature of the disorder, or the degree in which it has been administered, yet it has seldom been known to be attended with any bad effects; the patient generally has been relieved, and very frequently cured, but the ill consequences have even been more rare than those of inoculation. Electricity differs from other medical applications in this, that it acquires not so much a thorough knowledge of the distemper, as a peculiar nicety in conducting the operation. For, however paradoxical this may appear, it is certain that the electric shock is by no means prejudicial to persons in health, and therefore to electrify a sound part of the body along with a diseased one can do no harm. The degree of electrization must be regulated rather by the patient's feelings than by the species of disease, and therefore nosology is not an indispensably necessary branch of science to the medical electrician. There can be no doubt, however, that medical electricity will have every chance of being best applied, as well as improved, by skilful physicians and surgeons, whose knowledge of anatomy, as well as nosology, will enable them to direct the electrical fluid to the most proper part of the body, and to pass it through the most minute vessels, according to the nature of the disease, and the part of the body affected."

Insensible perspiration is one of the most important functions of the animal frame; and as it is promoted by electricity, it may fairly be inferred that electricity promises to render signal services in cases which will yield to no other power. The power of electricity over the blood, also, is evidenced by the fact of its increasing the force of its circulation. Thus, on insulating and electrifying persons who have been bled in the arm, the blood has sprung up to a greater distance than before. The same treatment will cause a fresh wound to bleed anew.

The medical application of electricity requires but few instruments in addition to the common electrifying machine. An electric jar, united with Lane's electrometer; an insulating stool of such a size that an ordinary chair may be set for the patient to sit in, and a pair of simple instruments called directors, are all that is necessary.

In the medical application of electricity, it is of importance to begin gently, and to persevere for some time. At first the electric fluid should be drawn by by a metallic point, the person being insulated and connected with the prime conductor, and the metallic point communicating with the earth. If after some days' trial no abatement of the disorder ensues, and t electrification has not the favourable effect even imparting an agreeable warmth, the electric fluid m be drawn by means of a wooden point; next to wooden point are sparks, and after these low shoc The electrification, whether in using the director otherwise, may be made through the clothes, unle they be very thick. In administering small shoc through thick clothing, it will be proper to pass m tallic points through the clothes, so as to be in conta with the skin.

In disorders of an inflammatory nature, electrici as it is a stimulant, should not be resorted to, unl at the commencement of those of a slight and lo nature, as of a catarrh, inflammation of the eyes, a swellings, where suppuration has not actually co menced. In chronic rheumatism, and chronic co plaints in general, electricity may always be appli with safety, and even if it should not effect a cure, seldom fails to afford relief. The toothache, when rheumatic origin, and attended with *caries*, seldo fails to yield to this application. Dr. Samuel Perr of New Bedford, in America, successfully appli electricity in two instances of locked jaw, after blee ing, cathartics, antismodics, the warm bath, an opium applied internally and externally had totall failed. In one case the complaint was entirely remove by three shocks; in the other, by an occasional shoc for a few days.

There is one method of applying electricity, th value of which has not as yet been fully ascertained; i is that of electrifying a bath, whether of warm or col water. This may be accomplished by lining the bat with non-conducting substances.

GALVANISM.

THE electricity evolved by the mere contact of conducting substances is called *galvanism*; a name given to this branch of science in compliment to Galvani, a celebrated physiologist of Italy, whose investigations first directed the attention of the public to the phenomena it comprehends.

While Professor Galvani was employed in dissecting some small animals, his wife observed that a dead frog, lying near the prime conductor of a common electrical machine, was much agitated when one of his assistants happened to bring the point of a scalpel near its crural nerves; Galvani, on being apprised of the circumstance, endeavoured to obtain a repetition of the effect, and found that the convulsions of the animal could be produced at pleasure, by drawing a spark from the prime conductor, at the time the scalpel was in contact with the nerve.

The novelty of the fact which he had thus been led to observe, stimulated him to pursue with ardour the track which had been opened to his view. His experiments were accordingly numerous, and he developed many interesting facts, which he communicated to the public in a work published in 1791. He found that a prepared frog, that is, the hind legs of a frog, with its crural nerves laid bare, constituted an electrometer of exquisite delicacy, being agitated by degrees of electricity far too minute to affect the best inorganic electrometer. An entire frog did not evince the same susceptibility, because its course was more extended. Electricity drawn from the atmosphere in the ordinary manner by means of a kite, produced the same effects on animals, according to its intensity, as that of the machine.

Accident soon assisted Galvani in his researches: having suspended some frogs from the iron palisades which surrounded his garden, by means of metallic hooks fixed in the spines of their backs, he observed that their muscles contracted frequently and involuntarily, as in the case above-mentioned from electricity. He at first thought that these effects might be dependent on a particular state of the atmosphere; but this conjecture was refuted by the discovery that the same movements could be produced at any time. by touching the animals with two different metals, which at the same time touched one another, either immediately, or by the intervention of some other substance capable of conducting electricity. The contractions were stronger when a metallic coating, such as tinfoil, was applied to the nerve.

Galvani supposed that the convulsions he had observed were produced by a disturbance of the electricity inherent in animals, which was identical with the nervous fluid, and that the metallic substances employed had not any other effect than that of transmitting the electricity from the muscles to the nerves, or from the nerves to the muscles, or two parts of the same muscle, provided two different metals were used. To explain the phenomena, he had recourse to the experiments of Bennet, who had some time before observed, that when plates of different metals were brought into contact, one of them transmitted a portion of its electricity to the other, and when separated, they evinced signs of opposite states of electricity. When the plates, for instance, were one of copper, and the other of zinc; the former, while the two were in contact, gave a portion of its electricity to the latter. Hence, when they were separated and examined by the electrometer, the copper exhibited signs of negative electricity, and the zinc those of positive. Volta therefore concluded, that the electricity evolved in the experiments in question, arose from the contact of the different metals, and the convulsions of the animals operated upon, were merely the consequences of the stimulus applied to their nerves and muscles, which were thus evinced to be most delicate electrometers.

The first stage or epoch in the history of galvanism, must be considered that in which it was observed that excited electricity produced muscular contractions in dead animals; the second, is that in which it was observed that different metallic bodies, by mere contact, produced the same kind of contractions; the third, and most remarkable one, commences with Volta's admirable discovery of the means of accumulating the galvanic influence. This invention, which justly confers so much celebrity on its author, is, in galvanism, analagous to that of the Leyden phial in common electricity, and became, like the phial, the precursor of the most brilliant discoveries; and philosophers can indeed as yet form but a very imperfect judgment of the consequences to which it will lead. It is called the Voltaic pile, and consists in combining the effects of a number of plates of different metals, by which means a galvanic battery, capable of giving a shock, is constituted. As silver and zinc had been found, when a single piece of each was employed, to have the greatest effect in producing muscular contractions, these metals were selected by Volta for his battery. The silver plates generally consisted of coins, and the plates of zinc were of the same size. The like number of pieces of cloth, pasteboard, or leather, of the same size, and saturated with a solution of common salt were also provided. These substances were piled upon each other in the following order: first, zinc, then silver, then wet cloth; then again, zinc, silver, wet cloth, till by this regular alternation the pile became sufficiently high.

If the height of the pile was considerable, it was usually supported by three pillars of glass or varnished wood. The pile thus formed, was found to unite the effects of as many pairs of plates as it contained. A pile of fifty pairs of plates, with as many corresponding pieces of wet cloth, was found to give a pretty smart shock, similar to an electric shock, every time that a communication was made between the top and bottom of the pile. It was found however, that little or no shock was perceived, when the hands, or other parts applied, were not previously moistened. It was also observed, that the effects were increased when a larger surface was exposed to the action of the pile. If the communication was made by touching the pile with the tip of each finger merely, the effect was not perceived beyond the joint of the knuckle; but if a spoon, or other metallic substance was grasped in moistened hands, the effect was felt up to the shoulder. If the communication be formed between any part of the face, particularly near the eyes, and another part of the body, a vivid flash of light, corresponding with the shock is perceived. This phenomenon may be more faintly observed, by placing a piece of silver, as a shilling, between the upper lip and the gum, and laying a piece of zinc at the same time upon the tongue; upon bringing the two metals into contact, a faint flash of light generally appears. It is singular, that this light is equally vived in the dark with the strongest light, and whether the eyes be shut or open.

Volta contrived another variety of the galvanic battery. The pairs of plates were soldered to each end of a bit of wire, which was afterwards bent into an arch so that the plates became parallel to each other. Glass cups were then filled with a solution of common salt, and ranged side by side; the metallic arcs were so placed, that the silver plate was immersed in one cup, and the zinc plate in another; and each glass, except the extreme ones, contained one plate of each metal. Its effects are similar to those of the pile, when the circuit is completed by a communication between the liquid of the first and last glass.

The Voltaic pile, as well as the battery, are now but little used, having been superseded by batteries of much more convenient form, particularly when a great accumulation of galvanism is required. In using the pile for example, it is tedious, after the cloth has become dry, to take the whole of the pile in pieces to moisten it, and the battery with glasses is deficient in compactness. Cruikshank, of Woolwich, therefore, invented a battery commonly called from its form, a galvanic trough. It consists of a trough of baked wood, about three inches deep, and three inches broad. The two sides of this vessel contain a number of perpendicular grooves, opposite each other, and about three-eighths of an inch apart. Into each pair of the grooves is put a plate of zinc and silver, or zinc and copper soldered together at the edges. These double plates are fastened in the grooves by means of a cement composed of five parts of resin, four of bees' wax, and two of powdered red ochre. All the cells between the plates must be perfectly water tight, and care must therefore be taken to run in the cement so as to secure this point. It will be found convenient, and will facilitate the business of fixing the plates, if they be heated till they can only just be handled, and smeared at the edges with the cement before they are put in. Any communication between the cells would destroy the effect.

The order of metals in a trough must be the same as in the pile, that is, the different metals must be next each other, and supposing zinc and copper to be used, if zinc be the outermost at one end, copper must be the outermost at the other.

The length of the trough is of course determined by the number of plates it is to contain, and the general rule is not to make the troughs heavier than one person can conveniently lift: fifty pairs of plates are a common number.

When the plates are properly fixed, the kind of fluid with which they are to be filled must be considered; water will answer only in a very slight degree; it has been found that the effect of the trough has been greatly increased by the use of liquids which are capable of oxidating, or exerting a chemical action on, at least, one of the metals; the water is, therefore, acidulated, or some common salt or muriate of ammonia is dissolved in it. Having filled the cells, the uppermost edges of the plates must be dried with a towel, to prevent any communication in that way.

When a communication is made between the first and the last cell, the same effects take place as when a communication is formed between the top and bottom of Volta's pile, only in a degree proportioned to the difference of acting surface.

In performing experiments, the communication between the extremities of a battery is usually completed by inserting a wire at each end, and the extremities of these wires being brought nearly into contact, the galvanic action is exerted on any substance interposed between them, by which means very slender wires, or thin leaves of metals, or pieces of charcoal may be consumed; the action of galvanism upon inflammable bodies is astonishingly powerful, and the exhibition of it upon metals is particularly interesting.

When a great combination of galvanism is wanted, it may be obtained by a combination of troughs. Pieces of copper, bent so as to dip into the adjoining cells, connect the troughs together, and the wires connected with the ends, act on the substances with the accumulated force of the whole number of troughs employed. In thus connecting batteries, care must be taken that the zinc end of one trough be next to the copper end of the other.

GENERAL VIEW OF GALVANISM.

It has been much contested, whether galvanism and electricity are owing to the operation of the same fluid, but the question appears to be now satisfactorily decided in the affirmative. A principal argument in favour of their being different, was, that galvanism decomposed water, an effect of which electricity was not known to be capable. But Dr. Wollaston not only decomposed water by electricity, but produced, by the same agent, a variety of other effects, which had been previously considered as exclusively producible by galvanism. It appears, therefore, that the principal difference between electricity and galvanism consists in the mode of exciting, accumulating, and applying the fluid.

It will be proper to observe that the conductors of galvanism are divided into two classes. The first class includes dry and good conductors, such as metals and charcoal; the second class includes water and other oxidating fluids, and the substances which contain these fluids. This second class might be subdivided into species; for substances not themselves good conductors, if merely containing or moistened with a fluid, are not equal in conducting power to the fluid itself.

From the various researches of philosophers the following results have been obtained:—

In common electricity, the fluid is excited by the rubbing of an electric and non-electric conductor, and without the electric no effect of this sort can be produced. In galvanism, the fluid is excited by the conductor alone, without the intervention of electrics, being evolved by the chemical agency of the substances employed; for Sir H. Davy discovered that the electricity is produced by a chemical action of the different substances on each other, that the effect is greater or less in proportion as this action is so, and that therefore two dissimilar metals are not essential to the evolutions of galvanism.

To produce the galvanic action, three different substances at least, which are conductors of electricity, must be placed in contact, so as to form a circuit from one to another, for no sensible effect is produced from two conductors, nor from three when the communication between any two of them is broken by an electric; hence such a combination of three different conductors is called a simple galvanic circle.

It seems to be indispensably requisite, that in a simple galvanic circle the conductor or conductors of one class should have some chemical action upon the other conductor or conductors; without which circumstance the combination of three bodies will have either no galvanic action at all, or a very slight one. Further, the galvanic action is evidently proportionate to the degree of chemical agency, which seems to show that some chemical action is the primary cause of the electric phenomena. The most active circles of the first order, are two solids of different degrees of oxidability and a fluid capable of oxidating at least one of the solids. Thus gold, silver, and water do not form an active galvanic circle; but the circle will become active, if a little nitric acid, or any fluid decomposable by silver is mixed with the water. A combination of zinc, silver, and water is found to oxidate the zinc, provided the water holds some atmospherical air, and especially if it contains oxygen gas. But zinc, silver, and water containing a little nitric acid, form a more powerful galvanic circle, the fluid being capable of acting both upon the zinc and upon the silver. The most powerful galvanic combinations of the second order, are when two conductors of the second class have different chemical actions on the conductors of the first class, at the same time that they have an action on each other. Thus copper or silver, or lead, with a solution of an alkaline sulphuret, and diluted nitrous acid, forms a very active galvanic circle.

After Volta had discovered the pile, it became an interesting object of inquiry to ascertain, with as much minuteness as possible, the combinations of substances which produced the greatest effect. A vast number of experiments were tried, with this view, by different persons, and at the Royal Institution, by which the following results were obtained:—

Galvanic Circles of the first Order, viz., which consist of two Conductors of the First Class, and one of the Second.

Zinc, with gold, or charcoal, or silver, or copper, or tin, or iron, or mercury; and water containing a small quantity of any of the mineral acids.

Iron, with gold, or charcoal, or silver, or copper, or tin, and a weak solution of any of the mineral acids.

Tin, with gold, or silver, or charcoal and a weak solution of any of the mineral acids, as above.

Lead, with gold or silver, and a weak solution, as above.

Any of the above metallic combinations and common water, viz., water containing atmospherical air, or especially water containing oxygen air.

Copper, with gold or silver, and a solution of nitrate of silver and mercury; or the nitric acid; or the acetous acid.

Silver, with gold and the nitric acid.

Galvanic Circles of the Second Order, viz., which consist of one Conductor of the First Class, and two of the Second.

Charcoal, or copper, or silver, or lead, or tin, or iron, or zinc, with water, or with a solution of any hydrogenated alkaline sulphuret, capable of acting on the first three metals only; and diluted nitrous acid or oxygenated muriatic acid, &c., capable of acting upon all the metals.

The history of philosophy affords many examples of observations which have remained isolated and useless for ages, and which, though often desired or discredited, have by the progress of discovery grown into importance, and become parts of a beautiful system, contributing at the same time essentially to the early maturity of some departments of knowledge. Hence those who have accurately detailed a single new phenomenon, which appeared to have no connexion with any thing useful, or any thing known, have in fact often been performing a work which should give celebrity to their names, by the direction it has given to inquiry, and the light it has thrown on subsequent researches.

In galvanism, several instances of the kind alluded to have occurred, and some of them it may be curious to mention.

A long time prior to the establishment of galvanism as a science, it had been observed, that if two different metals were placed in contact under water, they were subject to a rapid oxidation, though the water had no perceptible action upon them when they were alone.

It had also been observed that ancient inscriptions, made of mixed metals, were totally defaced, while those made of pure metals were in excellent preservation.

When metals have been soldered by means of other metals, they were found to tarnish about the places where they were joined; and the copper sheating of ships, when fastened by means of iron nails, soon corrodes about the place where the different metals touch each other.

It had been generally affirmed that porter drank out of a pewter vessel, has a taste different from that drank out of a glass, or earthenware.

It is now evident that in all these cases the metals produce these effects, by their galvanic action on each other.

The zinc end of a battery is considered to be plus, or positive; and the copper end to be minus, or negative.

Galvanic batteries, containing an equal quantity of similar metallic surface, have different effects, if the size of the plates be different. The greater the number of the plates, the stronger is the shock which they will give; on the contrary, the larger the plates, the greater is their power of deflagration; the extent of surface in each case supposed to be the same.

Different animals are susceptible of galvanism in very different degrees. In cold blooded animals this susceptibility sometimes continues for several days after death; in the more perfect animals, as man, it continues only for a few hours, and sometimes ceases in a few minutes. A fish, with the organization of its head completely destroyed by bruises, preserves its irritability longer than if it had not been thus treated.

Frogs have been found the most convenient subjects for galvanic operations. Galvani prepared these animals by skinning their legs when recently dead, and leaving the legs attached to a small part of the spine, but separated from the rest of the body. The strongest contractions are produced when the galvanic electricity is caused to pass through the nerve to the muscles. Frogs which have been galvanized very quickly become putrid.

Perhaps, most of those who try galvanic experiments merely for the purpose of amusement, would choose to dispense with the skinning of frogs. It may, therefore, be observed, that an ample proof of the power of galvanism over the dead animal muscle, may be obtained by galvanising any animal killed for domestic use. It will only be necessary to point the wires from the battery, and to penetrate the skin with them, at the two parts at which such a communication is intended to be made.

The medical uses of galvanism cannot yet be fully estimated. In some cases it has proved beneficial; in others, it has had no effect whatever; and in others, an unfavourable effect has been attributed to it. The cases in which it is in general most eligible to try it, are those for which common electricity is proper, and has failed. In instances of numbness, palsy, and suffocation, it has proved highly advantageous.

Various hypotheses have been offered to account for the phenomenon of galvanism; but that which appears to be the most comprehensive, considers them as of an electrical nature. During the combination of a metal, and, perhaps, of other substances, with oxygen, a quantity of electricity, it is supposed, is liberated or generated. In proof of the similarity of electricity and galvanism, Dr. Wollaston observes, that both appear to depend upon oxidation, for an amalgam not liable to oxidation, such as of gold and platina, will not excite an electrical machine, and the effect of any amalgam is in proportion to the ease with which it is oxidated.

To account for the difference in the effects between galvanism and electricity, it is asserted, and seems to be a well established fact, that galvanism is electricity in a state of little condensation. In proof of this, it is found that a common electrical jar or battery, may be charged by means of a galvanic battery; one wire from which, for this purpose, must communicate with the inside, and the other, with the outside, coating of the jar: the charge is given in a moment, but it is low, and such only as the jar would receive from a few turns of the ordinary electrical machine. Hence it is not difficult to explain, why the galvanic should be the greatest from a numerous series of plates, while the largeness of the plates is most essential to deflagration; for the force of the electric shock depends upon the *intensity* of the electric fluid, while the combustion depends very much upon its *quantity*. If, then, six large pairs of plates, and six hundred small ones, contain the same surface, and produce equal quantities of the electric or galvanic fluid; yet, as in the latter series, the product is confined to narrow limits, and acquires probably a fresh impulse from every addition to its quantity in passing from plate to plate through its lengthened course, it arrives at the extremity of the apparatus in a state of much greater intensity, than when only a few plates are employed.

We shall make but one remark more:—the galvanic investigations of Sir H. Davy tend to establish an opinion, that all substances which have a chemical action on each other, are in opposite electrical states, and that this difference of states, is the cause of such chemical action. Evidence is, however, wanting to confirm this beautiful hypothesis, and, consequently, it would be useless to show how it ought to modify chemical, galvanic, and electrical theories.

THE THERMOMETER.

ITS HISTORY AND CONSTRUCTION.

The invention of the thermometer, like almost every discovery of great utility, has been claimed for different philosophers; and national vanity has occasionally been enlisted in support of the rival claimants. There seems but two, however, whose titles are worthy of notice.

The Italian writers generally give the honour to their countryman Santorio Santorio, long a physician at Venice, and afterwards a professor at Padua, who flourished at the beginning of the seventeenth century, and who had obtained just celebrity by his discovery of the insensible perspiration of the animal frame. The Dutch philosophers, on the other hand, unhesitatingly ascribe it to Cornelius Drebbel, a physician of Alkmaar, who appears to have enjoyed a high reputation as a chemist, a mathematician, and an inventive mechanical genius.

Santorio expressly claims the invention as his own, and he is supported by Borelli and Malpighi. The title of Drebbel is considered as undoubted by Boerhave and Musschenbroek. It would now, perhaps, be difficult to decide the controversy; but it is worthy of remark, that Santorio was born in 1561, and died in 1636, did not publish his claim to the invention till 1626; and although thermometers are alluded to by Robert Flud, within the first quarter of that century, yet as he travelled both in Germany and Italy for six years, we can draw no inference from that circumstance. Certain it is, that thermometers were constructed about the same time, both in Italy, and in Holland, on the same principle: and though the instruments of Drebbel were well known in Holland and England before the fame Santorio appears to have reached the North West of Europe, the most recent writers have generally considered the latter as the real inventor of the thermometer. It is, however, by no means improbable, that each may be justly entitled to the merit of a discoverer.

Be this as it may, the instrument, from its imperfect construction, was of very little use in the hands of either, and required the successive labours of different philosophers to render it a tolerably accurate indicator of the variations of temperature.

The thermometer, ascribed to Santorio and Drebbel, is precisely the same in form and principle. It consists of a glass tube, with a ball blown on one of its extremities, and having the other end open. A portion of the air in the ball is expelled by heat, and then the open end of the tube is immersed in any liquid contained in the cup. As the ball cools, the included air diminishes in volume, and the liquid is forced into the stem by the pressure of the atmosphere, until it replaces the volume of air which was expelled by the heat. When a heated body is applied to the ball, the air will again be expanded, and depress the liquid in the stem; and if this stem be a cylinder, a scale of equal parts applied to it will enable the observer to form some idea of the difference between the relative temperature of bodies applied to the ball. On the removal of the heated body, the volume of the included air again diminishes, and the liquid again rises in the stem by atmospheric pressure, until the elasticity of the air within the instrument is in *equilibrio* with that of the surrounding atmosphere. Instruments constructed on this principle are called *Air Thermometers;* because the action depends on the elasticity of air; and from their having been originally employed to mark the changes of atmospheric temperature, they are described by the older writers under the name of weather-glasses; a denomination also given to barometers.

Drebbel appears to have devised a variety of the instrument more delicate in its indications. The globular form of the common bulb, and its small size, rendered it less susceptible of slight changes than a flattened bulb of larger diameter.

In the obscure and often almost unintelligible writings of our countryman Dr. Robert Flud, published at the beginning of the seventeenth century, frequent mention is made of the thermometer, or as he calls it *speculum calendarium;* and the common air is repeatedly figured in his singular work, *De Philosophia Moysiaca*, published in 1638, with its stem divided equally into an ascending and descending series, each of seven degrees, respectively appropriated to summer and winter. It is obvious that the size of an air thermometer, on such principles, is only limited by convenience, and the length of the column of liquid which the pressure of the atmosphere can sustain in the tube. As originally made, they were unwieldly, they could not be applied to high temperatures, and were besides, liable to two very important objections, as indicators of the atmospheric changes of temperature,—they were liable to be affected not only by heat and cold, but by the varying pressure of the atmosphere and the scales adapted to them were arbitrary, and withont fixed points for the comparison of observations made with different instruments.

The first objection was foreseen and obviated by the scientific members of the Florentine Academy, assembled under the patronage of the Grand Duke of Tuscany. In the first article, in the published transactions of that learned body, we find a full description and delineation of a thermometer from which the influence of atmospheric pressure is excluded. The expansion of spirit of wine is employed to ascertain the temperature, instead of the dilatation of air; and the instrument is sealed *hermetically*, as it is termed, or has its orifice closed by melting the glass, after the introduction of as much spirit as fills the bulb and a portion of the stem. The method employed by the Florentine academicians is nearly that still used by the makers of the instrument; namely, by heating the bulb in the flame of a lamp, to expel the air, and then immersing the open end of the tube in the liquid destined to fill the thermometer. As the ball cools the atmospheric pressure forces the liquid into the stem and ball, to supply the *vacuum;* and the orifice is closed by melting with the blow-pipe the end of the tube, from which any excess of the liquid may be previously expelled by again heating the ball.

The Florentine Academicians appear also to have been aware of the necessity of adapting some fixed scale to the tube; but their attempts were not very successful. They described the thermometer as consisting of a ball and tube of such relative size, "that on filling it to a certain mark of its neck with spirit, the cold of snow and ice will not cause it to fall below 20 degrees measured on the stem; nor, on the other hand, the greatest heat of summer expand it more than 80 degrees." This method is evidently erroneous, inasmuch as the last point could be of no determinate temperature; and their system of graduation is in itself rather rude. The tube is directed to be divided by compasses into ten equal parts, these divisions are to be marked "by a little button of *white* enamel; and these may be further sub-divided by the eye, and the intermediate degrees marked by buttons of glass, or of *black* enamel."

This instrument was variously modified by them to suit different purposes. The ball was occasionally enlarged, and the tube reduced in thickness to render the instrument more sensible; and in the work already quoted, we find a figure of a thermometer of this sort with the stem spirally twisted to render it more portable, and less liable to accident.

Another invention of the Florentine academicians to indicate changes of temperature may be here noticed. It consisted of hermetically sealed spherules of glass, of different specific gravities, introduced into a wide tube filled with pure spirit. The degree of the Florentine thermometer at which each sank was noted, and by hanging this instrument in an apartment, it somewhat showed the variations of the temperature of the surrounding air, though slowly. Imperfect as these attempts were, they paved the way to very important improvements in thermometers.

The indefatigable Boyle appears early to have turned his attention to the improvement of the thermometer, and his first attempts were on the air thermometer, or the weather-glass, as it was then styled. He rendered the instrument more convenient, by making one reservoir for the liquid and the air at the bottom of the tube; and thus the thermometer might be conveniently dipt in a fluid, or applied to any body for ascertaining its temperature. "The thermometer," he says, "being made by the insertion of a cylindrical pipe of glass (open at both ends) into a phial or bottle, and by exactly stopping with sealing wax, or very close cement the mouth of the phial, that the included air may have no communication with the external, but by the newly mentioned pipe." If a portion of any liquid sufficient to cover the lower extremity of the pipe be contained in the bottle, it is obvious, that the expansion of the enclosed air will elevate the included liquid in the cylindrical pipe; and this liquid will again descend on the contraction of the enclosed. Mr. Boyle likewise showed that no dependence could be placed on the indications of open air thermometers under different degrees of atmospheric pressure; and he states, that on plunging the bulbs of different thermometers in liquids of very different specific gravities, as mercury and water, the liquor in the stem stood at unequal heights though both had been long exposed to the same temperature.

The Florentine thermometer was about that time introduced into England, and duly appreciated by both Boyle and Hooke. The specimen seen by these philosophers was filled with *colourless spirit*, but they made use of spirits of wine, tinged with cochineal, "of lovely red;" and, says Boyle "'tis pleasant to see how many inches a mild degree of heat will make the tincture ascend in the cylindrical stem of one of these useful instruments." Boyle was fully aware of the imperfection of the scales hitherto applied to the thermometer, and sought to discover a remedy. He proposed to obtain a fixed point in the scale by marking the height of the liquid in the stem of the instrument, when the ball was placed in thawing oil of aniseeds, a point which he preferred to that of thawing ice, because the former could be obtained at any period of the year. His method of making two or more comparable thermometers, however, would be found extremely difficult, if not impossible in practice; it is best explained in his own words—"For if you put such rectified spirit of wine into a glass, the cavity of whose spherical, and that of its cylindrical part, are as near as may be, equal to corresponding cavities in the former glass, you may by some heedful trials, made with thawed and recongealed oil of aniseeds, bring the second weather-glass to be somewhat like the first; and if you know the quantity of your spirit of wine you may easily enough make an estimate, by the place it reaches to in the neck of the instrument, whose capacity you also know, whether it expands or contracts itself to the fortieth, the thirtieth, or the twentieth part of the bulk it was of, when the weather-glass was made."

Boyle mentions that an "*ingenious man*," (alluding to Hooke) had proposed the freezing of distilled water as a fixed point in the scale of thermometers, but he himself evidently gives the preference to the congealing point of aniseed oil. Dr. Halley proposed to regulate the scale by the uniform temperature of such a cavern as that under the Observatory of Paris, or the point at which *spirit boils;* and he also suggested the fixing of the scale from the *boiling of water*. This point he considered as an invariably fixed one, not liable to alteration from external circumstances; and the same idea was entertained by Amontons. With a single point so fixed, the method attempted by Boyle, Halley, and Hooke was to calculate the proportion of the stem to the ball, and thus to determine the increase in bulk of the whole liquid by a certain temperature.

Dr. Hooke appears invariably to have used in his thermometers spirits of wine "highly tinged with the lovely colour of cochineal, which he deepened by pouring in it some drops of common spirit of wine."

The sagacity of our illustrious Newton saw the importance of improving thermometers. He appears to have been early aware of the inconvenience of spirit as a thermometric fluid, and employed linseed oil to fill his thermometers. It has the advantage of being able to endure a very considerable temperature without endangering the bursting of the tube, and therefore can be applied to a higher range of temperature than a spirit thermometer. It has the advantage however, to be more sluggish in its movements, and to adhere much to the inside of the tube while it differs greatly in its fluidity at different temperatures. Newton perceived the inconvenience of having two fixed points in the construction of the scale; and he used the freezing and boiling points of water as the most suitable for this purpose.

Newton continued his scale of temperature farther by observing the rate of cooling of heated bodies, until he could apply his thermometer to them, on the principle that equal decrements of temperature take place in equal times. It was thus he estimated the temperature of iron heated to the utmost intensity of a small kitchen fire equal to 194 degrees, and in a fire of wood about 200 or 210 degrees of the same scale.

It is perhaps unfortunate for the philosophy of heat that more sublime and dazzling objects drew Newton's attention to other pursuits. Though he led the way to just views of the subject, neither he nor any of his predecessors appear to have been aware of the influence of the varying atmospheric pressure on the boiling points of liquids: nor do any of them seem to have considered that the varying expansions of the thermometric liquids at different temperatures, and the expansions of the glass of the instrument, must have materially affected every attempt to subdivide the stem of the thermometer into fractional parts of the whole bulk of the contained liquid.

One of these questions, however, seems to have about that time engaged the attention of philosophers, viz., whether equal increments of temperature caused equal expansions of the thermometric fluid. Dr. Brooke Taylor tried the experiment with an oil thermometer, by mixing definite portions of hot and cold water, and measuring the temperature of the mixture. His conclusion was in the affirmative; but the delicacy of his instruments was unequal to the solution of this nice problem, although he has the merit of pointing out how the problem is to be solved.

The Memoirs of the French Academy of Science contain several descriptions of thermometers, and an account of many interesting observations with these instruments; but the first alteration in their construction deserving of notice is the air thermometer of Geoffroy which, from the short description, appears to be an improvement on that of Boyle, inasmuch as it is not affected by atmospheric pressure. He describes his tube as without any opening, except one, which descends almost to the bottom of the ball, and there dips into a small portion of coloured liquid. It is not stated how the ball was joined to the tube, but it was most probably by cement.

M. Amontons clearly saw the importance of fixed points in the thermometric scale, and proposed to obtain them from the boiling point of water. His thermometer consisted of a tube four feet in length, ending below in a ball bent upwards, and open at the upper extremity. The measure of the temperature was the elasticity of a given portion of air included in the ball, and subjected to a pressure equal to two atmospheres, by adding to the usual atmospheric pressure that of a column of mercury of 28 French inches, which is equal to 56 inches under the usual pressure.

Although the idea of Amonton's was a fine approximation to a universal standard for a thermometric scale, the instrument is liable to such objections, that its principle seems scarcely ever to have been put in practice, except by its inventor.

While these attempts to perfect the thermometer were making in France, important improvements on it were effected in Germany and Holland, by the introduction of quicksilver as the thermometric fluid.

Science is indebted to Roemer, the celebrated astronomer of Dantzic, for this improvement, to whom the invention is ascribed by Boerhave, as well as the first idea of the scale now known as that of Fahrenheit. Thermometers of this construction were made by Gabriel Fahrenheit, a native of Dantzic, in so perfect a manner, that he has generally been considered as the original inventor; they were speedily spread over the north of Europe under his name, and to this day they maintain their acknowledged superiority in several countries, especially in Great Britain.

The mercurial thermometer was used by the Italian philosopher, Renaldini, before the end of the seventeenth century; and he proposed an ingenious method of graduating it between the freezing and boiling points of water. by successive mixtures of determinate weights of boiling and ice-cold water.

The great advantage of Fahrenheit's thermometer over every other previous invention, consisted in its applicability to a greater range of temperature, from the freezing to the boiling points of quicksilver; in its not soiling the containing tube, and in its receiving the impressions of heat and cold more readily, while its density rendered capillary tubes filled with it perfectly visible; and thus the instrument became more portable and delicate. We may also remark, that at the period of its invention, there was no other scale in use that could vie with it in accuracy; and it still possesses such peculiar advantages that the observer is seldom troubled with negative degrees, and from the number of its divisions has rarely, in ordinary operations, to use fractions of a degree.

It would now be a waste of time to describe the various thermometers which were in use in France and England before the time of Fahrenheit. They were all without fixed points in the scale ; and though they were vaunted as constructed after the models in the Royal Observatory at Paris, or in the apartments of the Royal Society of London, they gave most incongruous results. We shall therefore pass to the

Precautions necessary to be observed in constructing accurate Thermometers.

A general idea has been already given of the mode of constructing a Thermometer, but where so much accuracy is required there are many niceties that demand attention.

1. The tube should be of equal diameter throughout the whole stem. As obtained from the glass-house, the tubes are in reality frustra of very elongated hollow cones, which by extension, become more or less nearly cylindical, and as the divisions of the scale are usually equal, it is very important that the tube should not perceptibly differ from a true cylinder.

For these purposes, after a tube has been chosen by the eye as equal in calibre as possible, the best makers blow a bulb on it, and introduce a short column of mercury into the stem, perhaps an inch in length, which is accurately measured on a fine scale of equal parts, in different portions of the tube, as the column is, by the heat of the hand, moved from the bulb to the open extremity of the tube. Should the mercurial column subtend the same number of divisions on the scale in every part of the tube it may be considered as a perfect tube for a thermometer.

The late Mr. Wilson of Glasgow, introduced thermometric tubes of an elliptical bore. The advantage of this form is, that a very small column of mercury is much more visible when it is expanded at right angles to the line of vision. If due caution be taken to ensure the equality of the tube, this form answers well, especially for ordinary purposes; but where great nicety is required, we would recommend the cylindrical tube.

2. The form and proportion of the bulb may vary according to the purpose for which it is to be applied. The larger the bulb in proportion to the stem so much more delicately susceptible of changes of temperature will be the thermometer. The spherical bulb is to be preferred, for this shape is least likely to be affected by the varying pressure of the air; but when the bulb is very large, this form renders the thermometer less susceptible of minute changes of temperature, and pyriform or cylindrical bulbs are usually adopted.

In forming the bulb the mouth must not be employed to blow it, otherwise moisture will condense in the tube, which is expelled with much difficulty and if suffered to remain, will greatly impair the value of the thermometer. Good instrument makers use a small bottle of caoutchouc, or elastic gum, fastened by a thread on the end of the tube, while the other extremity is softened by the flame of a tallow lamp, urged by a blow pipe. By compressing the bottle, after the orifice of the softened end of the tube is closed by the aid of another rod of glass, a bulb is formed of any required size; but a neat workman will rarely consider the first blown bulb sufficiently well formed for his purpose. It is generally dilated till it bursts; the glass while still soft, is compressed into a rounded mass, and a fresh bulb formed of a regular shape and size proportioned to the calibre of the tube. Should the artist not intend to seal the tube immediately, he usually hermetically seals the other end of the tube to prevent the entrance of damp air and dust.

3. The necessary precautions used in filling ther-

mometers with mercury are plainly pointed out in Nicholson's *Chemistry*, viz:—

The mercury should be clean, dry, and recently boiled, to expel air as much as possible. Mercury is often cleaned by thermometer makers by agitating it in a phial, for some time, with sand, and then straining it through leather; for nice instruments it should be distilled from iron filings, or reduced from its sulphurets in clean iron vessels at a moderate heat.

The bulb, to be filled, is heated in the flame of a lamp, and the open extremity of the tube is immersed in the mercury; as the bulb cools, the pressure of the atmosphere forces the fluid into the tube and ball. The bulb should be but moderately heated at first, so as on cooling to become only half filled.

4. To ensure a delicate thermometer the mercury is next to be boiled in the thermometer. For this purpose a slip of clean paper is to be rolled tightly round the upper part of the tube, so as to form, beyond the orifice, a cup or cylinder capable of containing as much mercury as the bulb: secure this round the tube with a thread, put a drop of mercury into the paper cavity, and again apply the heat to the bulb, holding the tube by the part covered with the paper, the mercury will soon boil, and about one half of the contents of the ball will rush up into the paper cup. On removing the bulb from the candle the mercury will suddenly return. Repeat this operation again and again, until the speedy boiling of the mercury, and the diminished noise and agitation show that the whole has been well heated, and air and moisture expelled from it. Should there be the least moisture in the tube before this part of the operation, it is very likely to burst the bulb; and the same accident is likely to happen, if the mercury be too strongly boiled the first or second time.

5. The tube is now to be *hermetically sealed*, that is, closed by the fusion of the glass at the upper extremity,

which for this purpose is previously drawn to a capillary orifice. When it is intended to free the tube entirely from air, which is the best method with mercurial thermometers, heat is again to be gently applied to the bulb, which at the same moment is to be softened by another flame, and closed in the usual way, as soon as the mercury reaches the extremity of the tube. When the ball has cooled a little the sealing is rendered more secure by fusing the glass more fully round the top, so as completely to obliterate the orifice. If the vacuum be perfect, the mercury will fall to the extremity of the tube, on inverting the thermometer, unless the calibre be absolutely capillary; in which case capillary attraction will overcome the force of gravity, and the mercury will retain its position in the tube, in every situation of the instrument. Where there is a complete vacuum in the tube, the mercury must be well boiled before the sealing, as above directed: and when we choose a thermometer, the ready falling of the mercury, on inversion of the tube, is the best test we can have that the mercury has been well freed from air and moisture. This vacuum is not, however, so essential to the true action of the thermometer as was once supposed. A thermometer with a small dilatation of the tube when sealed, containing some common air, has lately been recommended as preferable to the instrument with a vacuum on the surface of the mercury.

6. We came now to the last and most delicate step of the process, the adaptation of the scale to the instrument.

In the manufacture of thermometers this is conveniently done by plunging the new instrument, along with a standard thermometer into two liquids at different temperatures: but the graduation of this standard instrument is a work of such nicety and importance, that a committee of seven members of the Royal Society was formed to investigate the subject, and their elaborate report is given in the Society's Transactions, where all the requisite circumstances are distinctly noticed, and the best manipulations minutely described.

Two fixed points are sought, and the freezing and boiling points of water are most convenient for that purpose. To find the first, nothing more is necessary than to place the thermometer to be graduated, after it is filled, in melting snow, or ice, in such quantity around the ball and tube, as to bring it to the desired temperature. When the mercury has become stationary in the tube, a mark is to be made on the tube with a file, just opposite to the top of the mercural column; and that mark fixes the freezing point of the scale of the instrument. The determination of the boiling point is much more difficult, because it is affected by atmospherical pressure, and even by the form of the vessel in which the water is heated. The Committee of the Royal Society recommend that the boiling point ought to be fixed under a barometrical pressure of 29. 80 inches.

CHEMISTRY.

Chemistry acquaints us with the various means of changing the properties of their bodies, by their action upon each other, whether in a simple or a compound state.

Chemistry is a science the utility of which is as boundless as its extent. What grasp at the knowledge of terrestial things can be conceived wider than that which embraces the action of all bodies, under all circumstances, upon each other; or what can be more important to the enjoyment of physical existence, than the best means of obtaining what this knowledge would give whatever is most conducive to its welfare. The growth and preparation of food, in short, every process on which the comforts of life, and the manual performances of man are dependant, can improve only with our knowledge of those bodies which are the instruments we must use to minister to our wants.

To trace in a regular manner the history of chemistry, though a task not devoid of interest, would contribute nothing to the elucidation of the principles of science. We shall therefore confine ourselves to such remarks of an historical nature as incidentally occur, and proceed immediately to useful details. 1. We shall shortly advert to the nomenclature of chemists, or the language which they use to designate the chemical state or differences of substances; 2, treat of that power of attraction between the particles of bodies upon which chemical changes depend; 3, give a general view of the implements and manipulations of the laboratory, but which the action of this attraction is modified; 4, enter upon the consideration of light and caloric, those unconfinable powers which so many of these manipulations elicit or require; 5, treat of simple substances in general, and from simple substances proceed to those which are compounded.

CHEMICAL NOMENCLATURE.

From the revival of learning after the fall of the Roman empire, to nearly the close of the seventeenth century, Chemistry had been chiefly confined to those who followed it with alchemical views.

Several eminent French chemists determined to take a comprehensive view of the subject, and to remodel the whole system of chemical nomenclature, a task which they completed in 1787. Their object was to reject all the old names which conveyed false ideas, but to preserve those which were not of this class, and to which custom had given a currency scarcely, and not usefully tc be checked; they at the same time introduced new terms of appropriate derivation; and the method of forming compound terms, so as to indicate the composition of compound bodies, was pointed out. This system of nomenclature possessed so such merit, that the adoption of it soon became general in France, and from thence it spread with great rapidity to other countries, where it was received either entirely, or with such improvements as experience warranted.—The objections which have been urged against it are futile; they have chiefly amounted to this, that it is not absolutely perfect, and will, by the progress of discovery, hereafter require to be modified. On the contrary, a high eulogium on its value and opportune establishment, is conveyed by the opinion of several eminent chemists, that the present state of chemistry could not be delineated by the language previously in use.

Our limits preclude the possibility of inserting a table of chemical terms in this place; but where opportunities occur, we will give the necessary explanations, as each subject gives occasion.

CHEMICAL ATTRACTION OR AFFINITY.

Of all the species of attraction, that of gravitation is the most general and uniform. As far as human investigation extends, it appears to be exerted on every equal particle of matter in an equal degree, and consequently upon all aggregates, in exact proportion to the quantity of matter they contain. Its action also prevails at all distances, and is entirely independent of the state or nature of materials.

The attraction cohesion, on the contrary, takes place only in minute distances; it differs greatly in degree between different substances, and between some substances is supposed to depend upon the strength of the attraction of cohesion between their particles, because the stronger this is, the more it opposes the disunity of the body. This species of attraction is often called the *attraction of aggregation*, because it simply tends to unite the particles of the same or different bodies into a mass, without any power to render the mass homogeneous—Capillary attraction is merely a branch of the attraction of cohesion.

Magnetic attraction is of a very partial nature; it is exerted only upon a very few substances, and by these substances only on each other.

All bodies are capable of exerting electrical attraction, but they must in the first place, according to the view which the present state of knowledge affords of the subject, be either over or under saturated with a principle called the electric fluid.

It is uncertain whether all these kinds of attraction result from principles essentially different, or are different modifications of the same cause.

The species of attraction, called *chemical attraction*, is also designated by the appellation of *chemical affinity*. This kind of attraction takes place only between the elementary particles of different bodies; and every integrant part of the compound which results from its effects, differs in its properties from any of its component parts. It is by this change of properties, that chemical combination, or the action of chemical attraction is distinguished from mere mechanical mixture.

Whatsoever relation the attraction of gravitation may have to the attraction of cohesion, the attraction of cohesion appears to be nearly related to chemical attraction, which appears only to be a refined degree of it, and the electric fluid performs an important part in creating the difference.

CHEMICAL UTENSILS AND OPERATIONS.

Of these utensils we can do little more than give their names in this place.

Crucibles and *Cupels* are the vessels commonly employed to contain the bodies submitted to the action of artificial heat. Crucibles are employed in the melting of metals and other operations of fusion. For low heats they are made of earthenware or porcelain, but for strong heats, of clay and sand. Cupels are formed of bone-ashes, with a small quantity of clay and plumbago in powder.

Retorts are globular vessels, formed with a long neck, and are made of earthenware, glass, or metal, according to the use for which they are designed. They are used in distillation.

Alembics.—The alembic is used for distillation, when the products are of too volatile a nature for the use of the retort.

Receivers.—A receiver or recipient is a vessel, usually of glass, in small operations, for receiving the volatile product from a retort or alembic. They are made of a globular form.

Evaporating-Vessels are made of wood, glass, metal, porcelain, or Wedgewood's ware. They are generally in the form of shallow basins.

The *Pneumati-chemical Apparatus* is a vessel containing a narrow shelf at the distance of three or four inches from its upper edge, and filled with water till the shelf is covered to the depth of an inch at least. The shelf is perforated with a number of small holes, to which funnels are adapted. When any permanently elastic gas is the product of distillation, and it is desired to fill receivers with the gas, without admitting the admixture of atmospheric air, this apparatus is used.

The *Gasometer* is constructed for the retention of gas, and for facilitating the drawing of it off as it is wanted.

Furnaces are of two kinds, viz., blast-furnaces and wind-furnaces, which are again subdivided into species, and distinguished generally according to the use which is made of them. Blast-furnaces are urged by the air, forcibly driven from bellows or cylinders; wind-furnaces by the draught of air arising from atmospheric pressure.

The *Blow-Pipe* is a brass tube, by which the flame of a lamp or candle may be directed upon any substance to be operated upon.

The *Thermometer* is a well-known instrument, for measuring the actual or relative temperature of bodies.

The list of chemical apparatus might easily be enlarged, but it will be more advantageous to combine the description of apparatus of less general application to the occasion for their use. Yet there are some articles which appear entitled to enumeration. It will be evident that in a place where all kinds of mechanical operations are constantly resorted to, that a large strong bench will be of considerable importance. Convenient small tables should also be at hand, for supporting mortars, an anvil, &c. A large vice is also a machine of great utility, and the use of it also implies that of hammers, rasps, files, saws, and other implements for working wood and metals.

Mortars, with their pestals, are made of iron for coarse purposes; for other occasions they are made of glass, Wedgewood's ware, and agate. Levigating stones are best made of porphyry. With the mortar and levigating stone, a spring-knife is useful.

Rods of glass, or porcelain, or even clean straws, are used for stirring mixtures. Glass and metal spatulas should also have their place. It is proper to have a pair of bellows; shovels, tongs, pokers, for managing the fire are of course necessary; and tongs of different shapes, for taking out crucibles, &c., from the furnace, should also be at hand.

A plentiful supply of water, fuel, and other things of constant necessity, need scarcely be alluded to.

CLASSIFICATION OF SUBSTANCES.

ALL the substances in nature, when classed according to their apparent or sensible properties, may be considered either as solid, fluid, aeriform, or etherial. But they may be distinguished by any of these characters, and yet be either simple or compound; to follow, therefore, such a mode of classification would not suit our purpose, as it would introduce confusion, by separating the consideration of substances so closely allied as to be almost identical. We shall therefore adopt the more general division of bodies into simple and compound, commencing with those which deviate the farthest from the solid state.

The arrangement we have proposed, introduces the following classification of

SIMPLE SUBSTANCES.

Ethereal.

Light .... Caloric (heat.)

Aeriform.

Oxygen.

Aeriform and Combustible.

Nitrogen .... Hydrogen.

Concrete and Combustible.

Carbon .... Phosphorus.
Sulphur .... All the Metals.

Light and Caloric.—The properties of these have already been fully discussed in a preceding part of this work.

Oxygen is the name given to the solid particles of oxygen gas, which is a combination of oxygen, caloric, and light, and is the simplest form in which oxygen can be obtained. Oxygen is called the radical or base of the gas; and the same mode of expression is used in other cases. It is invisible, perfectly elastic, like common air, and possesses neither taste nor smell.

Nitrogen.—Atmospherical air, after its vital qualities have been exhausted by combustion or respiration, leaves a residuum, which is elastic and invisible like itself, but wholly incapable of supporting life or fire. This is nitrogen gas, which is most easily described by including some of its negative qualities; it has no taste, it neither reddens vegetables, blue colours, nor precipitates lime-water; it is not absorbed by water. It unites to oxygen in several proportions; it also unites to hydrogen.

Hydrogen.—This gas has long been generally known by the name of inflammable air; it is the gas which miners call the fire-damp.

Carbon.—Vegetables, when burnt, leave a black, brittle, and cinerous residuum, which constitutes the greater part of the woody fibre, and is called *charcoal.* Charcoal contains a portion of earthy and saline matters, but when entirely freed from these and other impurities, a solid simple combustible substance remains, which is called *carbon.*

Sulphur, or brimstone, is a well-known substance of a yellow colour, brittle, moderately hard, devoid of smell, but not entirely so of taste.

Phosphorous is a yellowish transparent substance, of the consistence of wax. It is luminous in the dark at common temperatures. It is preserved by keeping it in water; the water has, however, the effect of rendering it opaque, and even exposure to light alters it in some degree.

Metals.—The metals, from their extensive and diversified utility, are amongst the most interesting classes of substances existing. They are supposed to be simple bodies, and not a single fact has ever been ascertained which shows that they can be converted into each other; and yet to accomplish this, alchemists exhausted their estates and their lives. The metals are distinguished by their possessing all or the greater part of the following properties:—hardness, tenacity, lustre, opacity, fusibility, mallability, and ductility; and they are excellent conductors of caloric, electricity, and galvanism.

COMPOUND SUBSTANCES.

Alkalies are possessed of the following properties: 1, They are soluble in water; 2, they have an acrid urinous taste; 3, they are incombustible; 4, they change brown; 5, they form neutral salts with acids; 6, they render oils miscibile with water. The alkalies are three in number, *potass*, *soda*, *ammonia*. Potass and soda are called fixed alkalies, because they are not volatilized, except by an intense heat; ammonia is called the *volatile* alkali, because it is converted into gas at a moderate heat. Oxygen is a component part of all the alkalies, and appears clearly in the case of the two fixed alkalies at least, to bealkalizing principle. The basis of the alkalies are metals.

Acids possess most or all of the following properties: 1, they excite the sensation called *sourness* or *acidity;* 2, they change the blue, green and purple juices of vegetables to red; 3, they combine with alkalies, earths and metallic oxides, with which they form the compounds called salts; 4, they combine with water in all proportions.

The number of acids which have been discovered, amount to thirty-seven, and are usually classed according to the substances from which they are derived, viz. Mineral acids, 9; Metallic acids, 7; Vegetable acids, 11; and Animal acids, 10.

Oxides.—When the oxygen united to any of the simple substances does not give it the properties of an acid or an alkali, the compound is called an oxide. Most of the metals are capable of combining with different proportions of oxygen, and a difference in the proportion of oxygen, gives a different colour to the oxide. Oxides are in general friable or pulverulent, and have the appearance of earths, but one of them is a fluid, and some of them are gases; there are six oxides, viz.—Oxide of Nitrogen, Oxide of Hydrogen, Carbonic oxide, Oxide of Sulphur, Oxide of Phosphorous, and Metallic oxides.

Earths.—The rocks, stones, and mould, which constitute the bulk of the globe, are found, upon being chemically examined, to consist of a few substances which are distinctly different from each other, though they have several properties in common. These substances are called earths.

1. Earths are incombustible, and when alone are scarcely alterable by the most intense heat.

2. They are either insoluble or very sparingly soluble in water or alcohol; when in combination with carbonic acid they are insoluble.

3. Their specific gravity is never five times greater than that of water.

4. They assume the form of a white dry powder when pure.

5. They have little taste or smell, at least when combined with carbonic acid.

6. They are not precipitated from their solutions in acids, by the prussiate of potass, like metallic oxides.

The distinct earths are the nine following; Alumine, Silex, Magnesia Zircon, Glucine, Yttria, Lime, Barytes, and Strontian. The three last named earths having, when pure, a caustic taste, solubility in water and the effect of changing blue vegetable tinctures to green, are often called *alkaline earths* and have sometimes been classed among the alkaline; but as they are infusible, and form insoluble compounds with carbonic acid, they certainly have a nearer relation to the general properties of the earths than to the alkalies.

STONES OR FOSSILS.

THE whole of the rocks, stones, and mould, which form so large a portion of our globe, so far as they have been examined, appear, as before observed, to have for bases one or more of the nine preceding earths, in different states of combination. To the eye, and in properties apparent to the senses, the variety which surrounds us seems infinite; we know very little of the processes which nature has employed to produce this variety; but the more skilful we become in chemical analysis, the more clearly we perceive that the elements of all things are few in number. We will ennumerate the leading varieties of fossils.

Aluminous Fossils.—Aluminous or argillaceous stones are very abundant; with some rare exceptions, they are all soft enough to be cut with a knife, and they do not like aluminous earths, fall to powder by mere immersion in water. They are six in number, viz.:—Corundum, Hornstone, Basaltes, Mica, Schistus, and Zeolites.

Silecious Fossils strike fire with steel, and they are generally susceptible of a fine polish; a great number of gems belong to this class. They are seven in number, viz.:—Quartz or Rock Crystal, Feldspar, Flints, Agates, Lapis Lazuli, Schorl, and Granite.

Magnesian Fossils are those which derive their character from magnesia, though they do not all contain a great proportion of this earth; they are distinguished by being greasy to the touch, and have neither the hardness nor infusibility of siliceous fossils. They consist of four, viz.:—Talc, Steatites, Serpentine, and Asbestos.

Calcareous Fossils are generally harder than the magnesian, but not so hard as the siliceous; none of them strike fire with steel; some of them imbibe water, and crumble by exposure to frost; others become harder by the same exposure. They comprise five kinds, viz.:—Crystalized Calcareous Stones, Marble, Stalactites, Gypsum, and Fluor Spar.

SALTS.

THE compound formed by the combination of an acid with an alkali, an earth, or metallic oxyde is called a SALT.

The term neutral salt was formerly given to all combinations of acids and alkalies, but the epithet neutral is now restricted to those salts in which the acid and the alkali completely saturate each other, and in which, therefore, the peculiar properties of neither can be detected.

The salts form a numerous class of bodies. Fourcroy reckons that there are one hundred and thirty-four species, and the number belonging to each species is often considerable. There can scarcely be less than two thousand distinct salts; but we shall only notice some of the most useful :—

Sulphates, of which there are six, viz. :—Sulphate of Allumine, Ammonia, Sulphate of Soda, Green Sulphate of Iron, Red Sulphate of Iron, and Sulphate of Copper,—are in general crystalizable, have some taste, but no smell; are precipitated by solution of barytes, and afford sulphurets when heated red-hot with charcoal.

Nitrates, viz. :—Nitrate of Potass, Nitrate of Soda, and Nitrate of Ammonia,—are soluble in water, and crystalizable; they deflagrate violently when heated to redness with charcoal, or other combustibles; sulphuric acid disengages from them a white vapour of nitric acid. By heat they are decomposed, and yield at first a considerable quantity of oxygen gas.

Muriates.—Muriate of Soda, of Potass, of Ammonia, and Hyper-oxymuriate of Potass, are the most volatile of all salts. They are at the same time the least decomposible; they may be melted and volatilized without undergoing decomposition. They effervesce with sulphuric acid, and white acrid fumes of muriatic acid are disengaged.

Carbonates.—Sub-carbonates of Potass and Soda, and Carbonate of Lime, effervesce, and yield carbonic acid, when sulphuric or nitric acid is poured upon them; all the alkaline carbonates are soluble in water, while those of the earths and metals are nearly insoluble.

Huates of Lime, and of Silex, are not decomposed by heat, nor altered by combustibles; when sulphuric acid is poured upon them they yield acrid vapours of fluoric acid, which corrodes glass.

Borates are all fusible into glass and assist the fusion of other bodies, particularly metals. The principal salts of this class are the sub-borate of soda, the borate of potass, of lime, of magnesia, and of alumine.

Acetates of Potass, of Ammonia, of Lead, and of Copper, are distinguished by their great solubility in water; by the decomposition of the acid when the solution is exposed to the air; by their being decomposed by heat, and by their yielding acid when mixed with sulphuric acid, and distilled.

Tartrates are decomposed by a red heat. The earthy tartrates are less soluble than the alkaline: but they are all capable of combining with another base, and forming triple salts.

The principle tartrates are those of potass, potass and soda of potass and ammonia, of lime, of strontian, and of potass and antimony.

Phosphates are capable of vitrification; are partially decomposed by sulphuric acid; are phosphorescent at a high temperature; are solube in nitric acid without effervescence; and may be precipitated from their solutions by lime water. The principal phosphates are those of potass, of soda, of ammonia of lime, of alumine, and of magnesia.

Prussiates.—The singular affinities of some of the prussiates render them interesting to the chemist; the simple prussiates, are, however, little regarded, because destitute of permanency, being decomposed merely by exposure to the air, unless united with a metallic oxide. The prussic acid does not appear capable of saturating an alkali; and the weakest acid known is capable of decomposing the prussiates of the earths and alkalies. The most important of the prussiates is that of iron; and of the triple prussiates those of potass, soda, lime, or ammonia with iron.

ORGANIC SUBSTANCES.

Vegetables, though infinitely diversified in their appearance and properties, are found to consist of a small number of simple substances; carbon is the basis of them all, after carbon, hydrogen and oxygen may be considered as forming the principal parts of them. Some vegetables contain nitrogen, others phosphorus, earths and metals, but these elements are not general; they being only to particular plants, or to plants in particular situations.

Plants derive a principal part of their nourishment from water: their roots imbibe the water, which is decomposed in them by the assistance of light and heat, and a part of its hydrogen becomes fixed, while part at least of the oxygen is given out by transpiration.

Animal Substances present us with the same constituent principles as vegetables: but the proportions of these principles are different. By destructive distillation they afford much ammonia, which is sparingly distributed in the vegetable kingdom; they also contain much nitrogen, of which the proportion is usually small among vegetables: and they are more abundant in phosphorus, while of carbon and hydrogen, which are abundant in vegetables, they contain but little.

Fermentation.—When vegetables and animals are deprived of life, the elements of which they are composed exert an action on each other; some of them enter into new combinations, others become entirely undecompounded; and the identity of the original substance is destroyed.

Fermentation is of three kinds: 1, the *vinous;* 2, the *acetous;* 3, the *putrid.* The two first kinds are peculiar to vegetable substances; the last is common both to vegetable and animal substances; though the change it indicates, is, in reference to animal substances, more generally called putrefaction.

Alcohol, or the purely spirituous part of liquors which have undergone the vinous fermentation and no other, is transparent and colourless like water; its taste is highly pungent, but agreeable. It is extremely inflammable, and when set on fire it leaves no residuum.

Ether.—If alcohol be mixed with its own weight of sulphuric acid, gradually added to prevent explosion, and the mixture be distilled in a sand-bath, the first product obtained is alcohol, but afterwards a very different fluid, which is equal in quantity to half the alcohol employed. This fluid is called *ether*, which is still more inflammable and volatile than alcohol, and equally as colourless. It is the lightest of all known fluids; its smell is fragrant and agreeable, but not powerful. Its taste is hot and pungent. Its combustion yields a blue flame, and rather more smoke than alcohol. Its internal use extends to all spasmodic affections; and it has latterly been applied in sufficient quantity to patients to deprive them of all sensation, and while in this state operations of a dangerous nature, such as amputations, have been successively conducted. But this experiment ought never to be attempted but by practical men of experience; as several deaths have occurred through its improper application.

FINIS.

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